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ORIGINAL

UNITED STATES DISTRICT COURT
NORTHERN DISTRICT OF TEXAS
DALLAS DIVISION

GENERAL ELECTRIC COMPANY,	§	3-10CV-276-F
Plaintiff,	§	CIVIL ACTION NO.________
v.	§	
MITSUBISHI HEAVY INDUSTRIES, LTD., MITSUBISHI HEAVY INDUSTRIES AMERICA, INC., and MITSUBISHI POWER SYSTEMS AMERICAS, INC.,	§	**JURY TRIAL DEMANDED**
	§	# 38261
Defendants.	§	

COMPLAINT FOR PATENT INFRINGEMENT

Plaintiff General Electric Company ("GE"), by its undersigned attorneys, for its complaint against Defendants Mitsubishi Heavy Industries, Ltd. ("MHI"), Mitsubishi Heavy Industries America, Inc. ("MHIA"), and Mitsubishi Power Systems Americas, Inc. ("MPSA") (collectively, "Defendants"), hereby alleges the following:

Nature of the Action

1. This is an action arising under the patent laws of the United States based upon infringement by Defendants of two patents owned by GE. GE seeks damages for Defendants' infringement and a permanent injunction restraining Defendants from further infringement.

Parties

2. GE is a New York corporation with its principal place of business in Fairfield, Connecticut. GE engages in the development, manufacture, and distribution of variable speed wind turbines and components. GE is the assignee and owns all right, title, and interest to U.S. Patent Numbers 6,879,055 and 7,629,705 (collectively, "Asserted Patents") and has full rights to sue and recover damages for all past, present, and future infringements of the Asserted Patents.

3. MHI is a Japanese corporation with its principal place of business in Tokyo, Japan. MHI engages in the development, manufacture, and distribution of variable speed wind turbines and components for importation, sale, and use in the United States, including in Texas and in this judicial District, through its U.S.-based subsidiaries MHIA and MPS named as co-defendants in this action.

4. MHIA is a wholly-owned U.S. subsidiary of MHI and is organized and existing under the laws of the state of Delaware with its principal place of business in New York, New York. On information and belief, MHIA engages in the development, manufacture and distribution of variable speed wind turbines and components for sale and use in the United States including in Texas and in this judicial District. MHIA has a registered agent for service of process in this judicial District: CT Corporation System, 350 North St. Paul St., Dallas, Texas 75201.

5. MPS is a subsidiary of MHI and is organized and existing under the laws of the state of Delaware with its principal place of business located in Lake Mary, Florida. MPS engages in the development, manufacture and distribution of variable speed wind turbines and components including in Texas and in this judicial District. MPS has a registered agent for service of process in this judicial District: CT Corporation System, 350 North St. Paul St., Dallas, Texas 75201.

Jurisdiction and Venue

6. This is an action for patent infringement arising under the patent laws of the United States, Title 35 of the United States Code. This Court has subject matter jurisdiction under 28 U.S.C. §§ 1331 and 1338(a).

7. This Court has personal jurisdiction over Defendants as Defendants have

regularly engaged in business in this State and District and purposefully availed themselves of the privilege of conducting business in this District, for example, by offering for sale, selling, distributing, and installing variable speed wind turbines at the Goat Mountain wind farm in San Angelo, Texas in this District and (for MHIA and MPS) by maintaining an office of business in Fort Worth, Texas and a registered agent for service of process in Dallas, Texas in this District and Division.

8. Venue is proper in this judicial District under 28 U.S.C. §§ 1391 and 1400.

The Asserted Patents

9. Plaintiff GE is the owner and assignee of United States Patent No. 6,879,055 ("the '055 Patent"), entitled "BASE FRAME FOR MOUNTING THE SHAFT OF THE ROTOR OF A WIND POWER PLANT ONTO THE PLANT TOWER." The '055 Patent was duly and legally issued by the United States Patent and Trademark Office on April 12, 2005. A true and correct copy of the '055 Patent is attached as Exhibit A.

10. Plaintiff GE is the owner and assignee of United States Patent No. 7,629,705 ("the '705 Patent"), entitled "METHOD AND APPARATUS FOR OPERATING ELECTRICAL MACHINES." The '705 Patent was duly and legally issued by the United States Patent and Trademark Office on December 8, 2009. A true and correct copy of the '705 Patent is attached as Exhibit B.

First Count – Infringement of U.S. Patent No. 6,879,055

11. On information and belief, Defendants directly, indirectly, contributorily, and/or by inducement, literally or under the doctrine of equivalents, have infringed and continue to infringe the '055 Patent by their manufacture, use, sale, offer for sale, and/or importation of products and services related to variable speed wind turbines, within this judicial District and

elsewhere in the United States, that infringe one or more claims of the '055 Patent and by their causing and inducing others to infringe one or more of the claims in the '055 Patent based on others making and/or using variable speed wind turbines supplied by the Defendants within this judicial District and elsewhere in the United States. An example of an infringing product is Defendants' 2.4MW wind turbine. Defendants are liable for their infringement of the '055 Patent pursuant to 35 U.S.C. § 271.

12. Defendants' activities have been without express or implied license from GE.

13. Defendants' infringement of the '055 Patent has caused, and unless enjoined will continue to cause, irreparable harm to GE. GE has no adequate remedy at law and is entitled to a permanent injunction against further infringement.

14. GE has suffered and will continue to suffer substantial damage to its business by reason of Defendants' acts of infringement of the '055 Patent as alleged herein, and GE is entitled to recover the damages sustained as a result of Defendants' acts pursuant to 35 U.S.C. § 284.

Second Count – Infringement of U.S. Patent No. 7,629,705

15. On information and belief, Defendants directly, indirectly, contributorily, and/or by inducement, literally or under the doctrine of equivalents, have infringed and continue to infringe the '705 Patent by their manufacture, use, sale, offer for sale, and/or importation of products and services related to variable speed wind turbines, within this judicial District and elsewhere in the United States, that infringe one or more claims of the '705 Patent and by their causing and inducing others to infringe one or more of the claims in the '705 Patent based on others making and/or using variable speed wind turbines supplied by the Defendants within this judicial District and elsewhere in the United States. An example of an infringing product is

Defendants' 2.4MW wind turbine. Defendants are liable for their infringement of the '705 Patent pursuant to 35 U.S.C. § 271.

16. Defendants' activities have been without express or implied license from GE.

17. Defendants' infringement of the '705 Patent has caused, and unless enjoined will continue to cause, irreparable harm to GE. GE has no adequate remedy at law and is entitled to a permanent injunction against further infringement.

18. GE has suffered and will continue to suffer substantial damage to its business by reason of Defendants' acts of infringement of the '705 Patent as alleged herein, and GE is entitled to recover the damages sustained as a result of Defendants' acts pursuant to 35 U.S.C. § 284.

Jury Demand

19. GE hereby requests a trial by jury pursuant to Rule 38 of the Federal Rules of Civil Procedure.

Prayer for Relief

20. WHEREFORE, Plaintiff GE respectfully requests the following relief:

A. That Defendants be adjudged to have infringed the '055 and '705 Patents;

B. That Defendants, their officers, agents, servants, employees, attorneys, and those persons in active concert or participating with any of them, be permanently restrained and enjoined from infringing in any manner the '055 and '705 Patents;

C. An accounting for damages by virtue of Defendants' infringement of the '055 and '705 Patents;

D. An award of damages pursuant to 35 U.S.C. § 284 to compensate Plaintiff for Defendants' infringement of the '055 and '705 Patents;

E. An assessment of pre-judgment and post-judgment interest and costs against Defendants, together with an award of such interest and costs, in accordance with 35 U.S.C. § 284 and 28 U.S.C. § 1961;

F. That Defendants be directed to pay Plaintiff's attorneys' fees incurred in connection with this lawsuit should the Court determine that this is an "exceptional case" pursuant to 35 U.S.C. § 285; and

G. Such other costs and further relief that this Court may deem just and proper.

Dated: February 11, 2010

Respectfully submitted,

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EXHIBIT A

US006879055B2

(12) **United States Patent**
Becker et al.

(10) **Patent No.:** **US 6,879,055 B2**
(45) **Date of Patent:** **Apr. 12, 2005**

(54) **BASE FRAME FOR MOUNTING THE SHAFT OF THE ROTOR OF A WIND POWER PLANT ONTO THE PLANT TOWER**

(75) Inventors: **Markus Becker**, Rheine (DE); **Roland Weitkamp**, Belm-Icker (DE); **Vincent Schellings**, Enschede (NL)

(73) Assignee: **General Electric Company**, Schenectady, NY (US)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 0 days.

(21) Appl. No.: **10/126,299**

(22) Filed: **Apr. 19, 2002**

(65) **Prior Publication Data**

US 2003/0080566 A1 May 1, 2003

(30) **Foreign Application Priority Data**

Apr. 20, 2001 (DE) 101 19 428

(51) **Int. Cl.**[7] **F03D 9/00**; F03D 1/06; F03D 11/00; F03D 11/04; F03D 7/02

(52) **U.S. Cl.** **290/55**; 290/44; 290/54

(58) **Field of Search** 290/44, 54–55

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Primary Examiner—Nicholas Ponomarenko
Assistant Examiner—Pedro Cuevas
(74) *Attorney, Agent, or Firm*—Blakely, Sokoloff, Taylor & Zafman LLP

(57) **ABSTRACT**

To facilitate transport and assembly during the erecting of wind power plants, a two-part base frame is proposed for the azimuthal adjustment of the gondola on the tower of the wind power plant, the lower part of which **16** has the azimuthal drive device **23** and the upper part **6** of which has the drive train **1, 2, 12, 13, 14**. Both parts are pre-assembled at the factory, set onto the tower, and screwed tight onto each other at their connection point **15**.

18 Claims, 3 Drawing Sheets

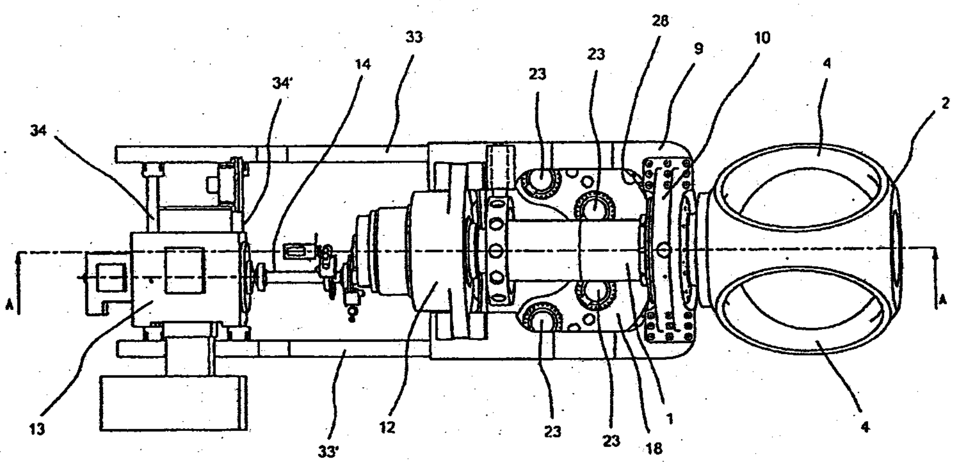

EXHIBIT A

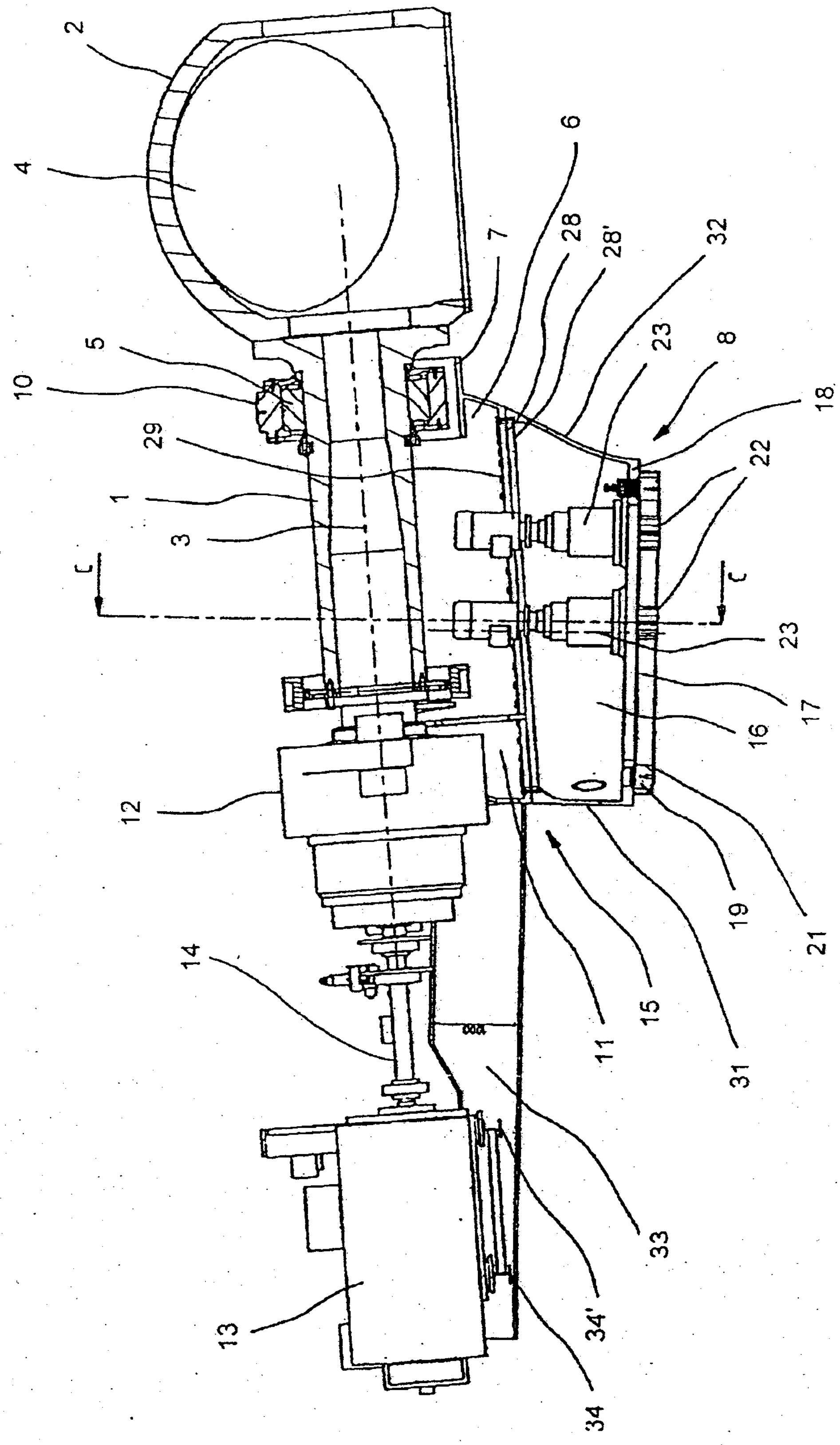
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Fig. 1

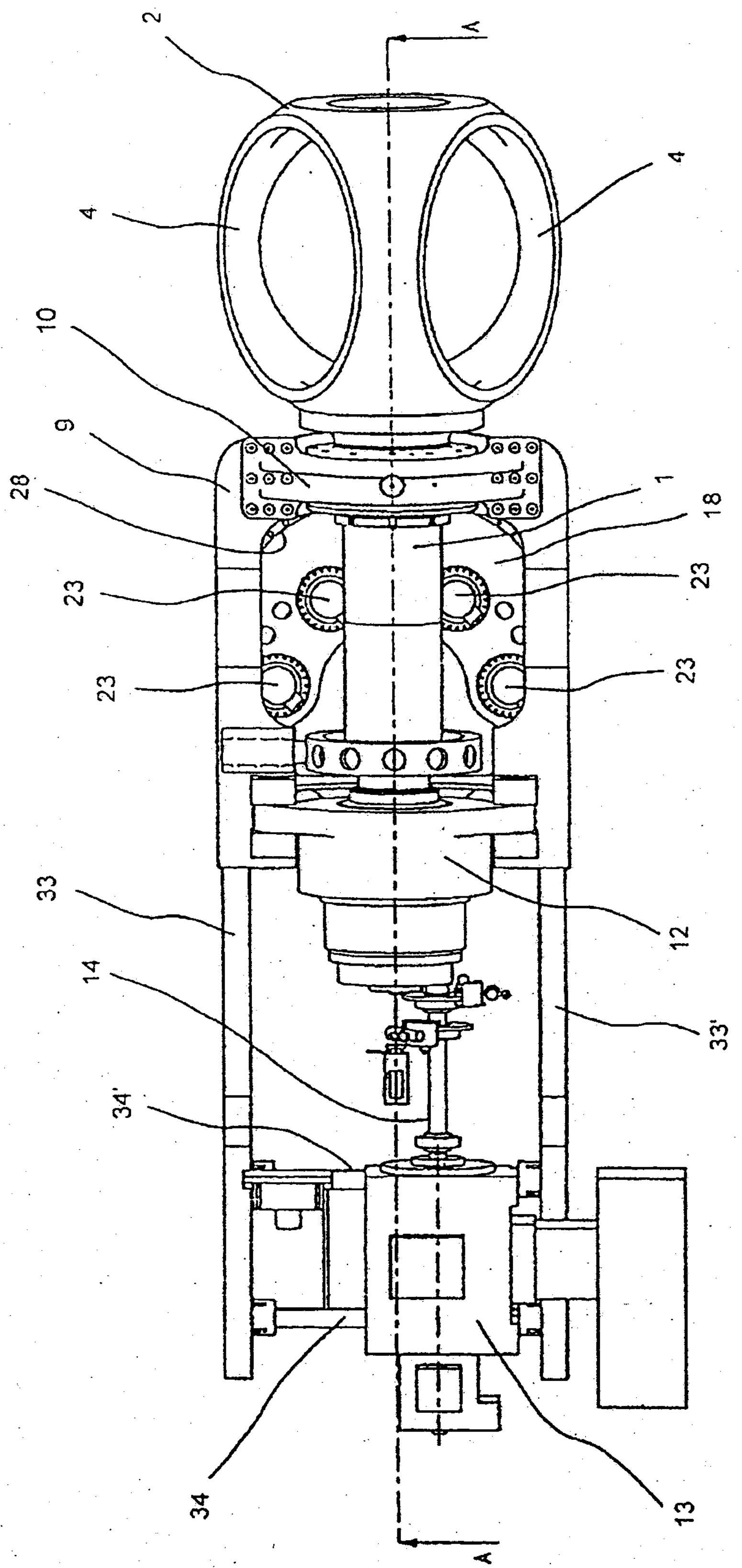

Fig. 2

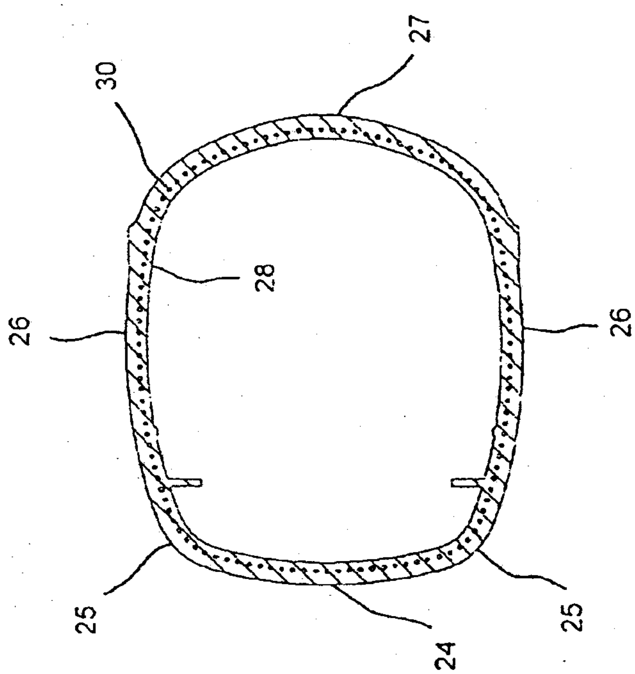

Fig. 4

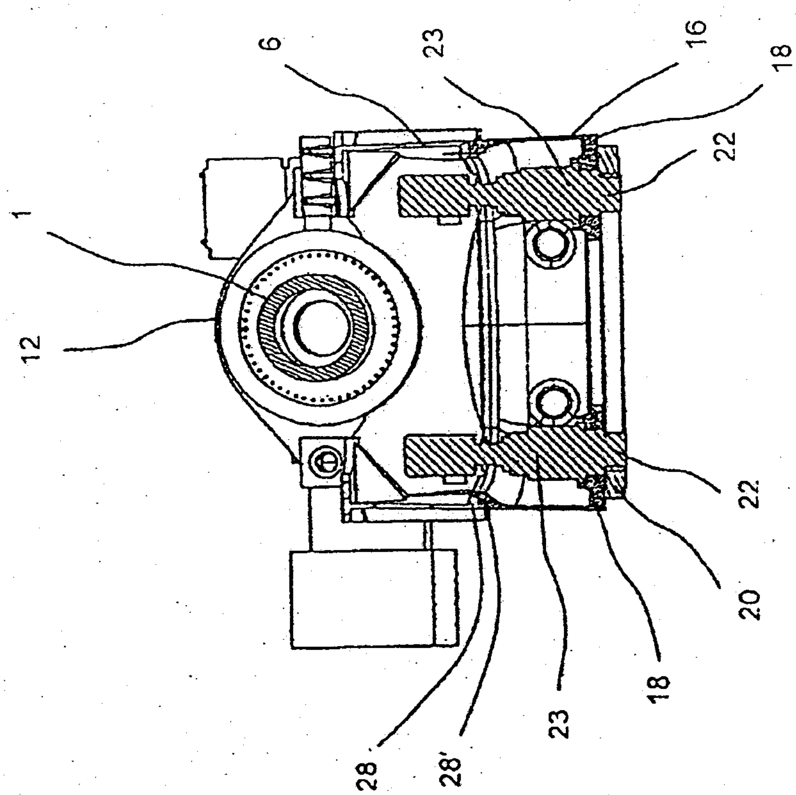

Fig. 3

BASE FRAME FOR MOUNTING THE SHAFT OF THE ROTOR OF A WIND POWER PLANT ONTO THE PLANT TOWER

The invention involves a base frame for the arrangement of a drive train on the tower of a wind power plant. The drive train is driven by a wind-driven rotor. The base frame is affixed onto the tower with an essentially horizontal orientation of the rotor axis so that it can rotate azimuthally around the essentially vertical axis of the tower and is constructed from an upper part that carries the drive train and a lower part that has an azimuthal drive device that is combined with the upper part at a connection point and functions for azimuthal rotation.

Known wind power plants, in which the rotor axis is arranged essentially transverse to the tower axis, i.e. essentially horizontally, and can be adjusted azimuthally as a function of the wind direction, usually have, at the upper end of the tower, an azimuthally adjustable machine housing, also called a gondola, in which the drive train is arranged, which has, for example, a rotor shaft, a gear which is connected to the rotor shaft on the input side and through which the relatively low rotational speed of the rotor is converted into a high rotational speed at the output of the gear, and a generator connected to the output of the gear, whereby in the gondola, if necessary, additional mechanical and electrical components required for the operation of the wind power plant can be housed. With increasing power of this wind power plant, the dimensions of this machine housing and the weight of the machine housing and the components housed in it become larger and larger. This presents a considerable problem in the erecting of wind power plants, because it is more and more difficult, with increasing dimensions and weight, to perform the transport to the building site and the assembly.

In regard to these difficulties, the purpose of the invention is to create a base frame of the type named at the beginning, which makes it easier to accomplish transport and assembly work associated with the erecting of the wind power plant, while having sufficient stability.

According to the invention, this purpose is achieved in that the connection point (15) extends along an essentially horizontal cross-section, which has a larger dimension in the direction of the rotor axis (3) than in the direction perpendicular to that.

By the two-part construction of the base frame, a division of the total mass and the total dimensions into two partial systems is achieved, each of which can be transported more easily to the construction site and lifted to the tower. Especially decisive in the process is the limitation of the transport height achieved by the two-part construction. An additional advantage consists in that for a crane capacity that is sufficient at the construction site, a complete preliminary assembly of the upper and lower parts can occur in the manufacturer's factory with the respective components to be housed. For example, the lower part can be assembled preliminarily with the azimuthal drive device and the upper part with the drive train, and if necessary, all additional components can be pre-assembled at the factory. At the construction site, only the lower part needs to be mounted onto the tower and the upper part needs to be mounted onto the lower part, while all other assembly work already anticipated at the factory is not necessary.

The construction of the connection point according to the invention is especially favorable in a structural-mechanical manner with regard to the forces that stress it. The forces acting on the wind-driven rotor are introduced along the

rotor axis into the upper part of the base frame. For the stress of the connection point caused by this, it is especially favorable that it has its largest dimension in this direction.

A functional embodiment form is distinguished in that the base frame has a hollow body (8) that is radially limited in relation to the tower axis by an essentially closed wall, whereby the cross-sections of this hollow body have, in its lower end area (17) that borders on the upper end of the tower, a circular contour that, for the cross-sections placed above it axially, making a transition into a contour that is elongated in the direction of the rotor axis (3), and the connection point (15) is arranged in the area of its elongated contours.

The circular-shaped contour of the radial hollow body cross-sections in the lower end area of the lower part function for the adaptation to the azimuthal adjustability in relation to the tower axis. By the smooth upward transition into the elongated cross-section contour, the hollow body adapts its shape to the components to be received by the upper part. Since the main introduction of force is done via the rotor arranged on the upper part in the direction of its rotor axis, an optimal adaptation of the connection point is achieved in a structural-mechanical manner by the arrangement of the connection point in the area of the elongated cross-section contours.

In an especially functional embodiment form it is provided that the connection point of the two parts extends into a plane that extends parallel to the rotor axis and perpendicularly to the tower axis. For the case, that in a known way the rotor axis does not extend exactly perpendicular to the tower axis, i.e. not exactly horizontally, in order to offset wind load-dependent deflections of the rotor blades, but instead rises only slightly up to the hub of the rotor, then the plane separating both parts preferably follows this rise of the rotor axis.

Furthermore, it is functional to construct the base frame in such a manner that each of the two parts have, in the area of the connection point, a flange that is essentially radial in relation to the tower axis and that has end faces facing each other that can be clamped together, whereby in particular both parts can be connected by screwed bolts going through the flange. Thus, it only necessary during the final assembly to set the upper part with its flange onto the flange of the lower part and to clamp together the two flanges in a non-positive manner. In particular, many holes which go through can be arranged in closely following one another along the circumferential flanges, which extend out from the inner wall of the hollow body, for example, and through these holes a correspondingly large number of screwed bolts is passed in order to screw the flanges tightly together during the final assembly.

In regard to the shape of the hollow body, it has proven to be especially functional that the elongated contours in the area of the connection point are constructed so that they are symmetrical to the rotor axis and have, at their end area that faces away from the rotor, a first section that extends crosswise to the rotor axis and is bent at its ends in the direction to the end area that faces the rotor, at its end area that faces the rotor, a second section bent towards the end area that faces away, and two side sections that connect the first section to the second section. This shape is especially favorable in regard to the mechanical rigidity of the hollow body. In the process, the first section is preferably arched slightly to the outside, whereas the two side sections, especially to limit the lateral dimension, run almost straight with a very slight arch to the outside and by this flattened shape contribute to the reduction of the transport width.

For these reasons, it is additionally functional in regard to the shape that the contours of the longitudinal sections of the hollow body parallel to the tower axis and to the rotor axis run essentially parallel to the tower axis in their area that faces away from the rotor and in their area that faces towards the rotor run at a distance from the tower axis which increases from the bottom to the top. This shape has the additional advantage that the area of the hollow body facing the rotor projects outwards from the bottom to the top relative to the tower in the manner of a ship's bow, whereby the rotor that rotates in front of it takes on a corresponding distance from the tower.

In the context of the invention, it is further provided that in the upper part in its area that faces the rotor, a recess for a rotor shaft bearing is constructed. By this, the bearing of the rotor shaft is achieved on the base frame in an especially simple way.

For similar reasons, it is functional that in the upper part in its area that faces away from the rotor, a recess for the support of a gear is constructed. In this way, the arrangement of the gear on the base frame is made easier.

An additional point of the invention consists in that the lower part has, on its lower end an area that borders the upper end of the tower, a flange directed radially to the inside, on which at least one servomotor of the axial drive device is arranged with the drive axis parallel to the tower axis and a pinion gear that is arranged rotationally fixed on the drive axis for combing mesh into an inner crown gear that is affixed on the upper end of the tower coaxially to the tower axis. This attachment of the servomotor to the flange of the lower part makes possible an especially simple design of the axial drive device. If the servomotor is turned on, the pinion gear driven by it combs with the inner crown gear affixed to the tower and causes in this way the azimuthal movement of the base frame. Usually, several of these servomotors, in particular, four servomotors, are provided, which are arranged in pairs symmetrically on both sides of a hypothetical plane positioned through the rotor axis and the tower axis.

In regard to the azimuthal drive device, it is further functional that the inner crown gear is constructed on the inner ring of a roller bearing whose outer ring is affixed to the lower part. In this way, the azimuthal twisting capability between the tower and the base frame as well as the axial attachment of the base frame to the tower is ensured.

An additional development significant for all embodiment forms consists in that on the upper part, two supports that extend away from its end that faces away from the rotor essentially in the direction of the rotor axis are arranged, on which at least one generator of the wind power plant can be supported. These two supports can also function for the support of additional mechanical and electrical components of the wind power plant. Functionally, the combined distance of the two supports measured crosswise to the rotor axis is greater than the crosswise dimensions of the generator and/or the additional components. In this case, the generators and the additional components are functionally supported on crosswise supports that span the separation distance. The generator and the possible additional components and also the gear can then be removed to the bottom between the two supports extending in the direction of the rotor axis for the purposes of assembly or disassembly, whereby if necessary, the crosswise supports must be disconnected from the supports extending in the direction of the rotor axis beforehand. The supports extending in the direction of the rotor axis do not have to run exactly parallel to the direction of the rotor axis. In particular, they can converge in the direction toward the end that faces away from the rotor.

In the following description, the invention is explained in greater detail with reference to the drawing. Shown are:

FIG. 1 a longitudinal section of a base frame through the tower axis and the rotor axis of a wind power plant with the structural units mounted on it according to the line A—A in FIG. 2,

FIG. 2 a view in the direction of the tower axis onto the base frame shown in FIG. 1,

FIG. 3 a cross-section through the base frame according to the line C—C in FIG. 1,

FIG. 4 a view of a connection point between a lower and an upper part of a hollow body of the base frame shown in FIG. 1 to 3.

In FIGS. 1 and 2, the shaft 1 and the hub 2 of the rotor of a wind power plant arranged on its one end can be recognized, whereby the rotor axis 3 around which the rotor turns is also shown. The hub 2 has, in the embodiment example shown, a total of three radial recess openings 4, which are azimuthally set off at equal distances relative to the rotor axis 3, for the ends of three rotor blades (not shown), the longitudinal axes of which extend radially to the rotor axis 3 and which can be turned in the recess openings 4 around their longitudinal axes in order to adjust their angle of attack. The shaft 1 is set in bearings near the hub 2 via a main bearing 5, which is affixed in a recess 7 of a hollow body 8 constructed in an upper part 6. In connection with FIG. 2, it is clear that the upper part 6 in the area of the receptacle 7 has an open edge 9, which lies in a hypothetical plane going through the rotor axis 3, which extends perpendicularly to the plane of the drawing of FIG. 1 and parallel to the plane of the drawing of FIG. 2. From this open edge 9, the receptacle 7 is hollowed out of the upper part 6 of the hollow body 8 in the shape of a semicircle in relation to the rotor axis 3. A semicircle-shaped bearing holder 10 that is complementary to the receptacle extends above it, and the holder 10 is clamped by bolts onto the open edge 9.

In the area of the upper part 6 which faces away from the rotor, a receptacle 11 is constructed, which functions to hold a gear 12 connected to the end of the shaft 1 which is opposite the hub 2. In the gear 12, the relatively low input side rotational speed of the shaft 1 is raised in order to drive an electric generator 13, which is coupled to the output of the gear 12 by a coupling 14. The upper open edge 9 of the upper part 6 also runs in this area approximately in the hypothetical plane extending through the rotor axis 3 and perpendicularly to the plane of the drawing of FIG. 1, and/or parallel to the plane of the drawing of FIG. 2, so that the approximately cylindrical body of the gear 12 lies halfway within the receptacle 11 as seen radially.

From out of its upper open edge 9, the upper part 6 of the hollow body 8 extends essentially crosswise to the rotor axis 3 up to a connection point 15 with a lower part 16 of the hollow body 8. The lower end area 17 of the lower part 16 opposite the connection point 15 functions for the connection to the upper end of the tower (not shown) of the wind power plant. For this purpose, the lower end area 17 has a flange 18 that is directed to the inside and radially in relation to the tower axis, which can be seen especially clearly in FIG. 3. On the outer end face of the radial flange 18 pointing to the upper end of the tower, the outer ring 19 of a large roller bearing 20 (shown only schematically in the drawing) is affixed, the inner ring 21 of which is provided with inner teeth. With these inner teeth, drive pinions 22 of a total of four servomotors mesh, which are arranged inside the hollow body 8 and are flanged mounted on the radial flange 18 in an orientation, parallel to the tower axis, of their drive shaft that drives the drive pinion 22. The four servomotors

23 are arranged on the radial flange 18 in pairs symmetrically to a hypothetical plane positioned through the tower axis and the rotor axis 3. The inner ring 21 is affixed to the upper end of the tower (not shown). As a result, by an activation of the servomotor 23, the entire base frame is azimuthally moved in relation to the tower axis whereby the rotor axis 3 is oriented according to the wind flow. In FIG. 1 it can be seen that the rotor axis 3 does not run perpendicularly to the tower axis, but instead increases somewhat to the hub 2. In this way, an open space is created for a wind pressure-related deflection of the rotor blades relative to the tower.

In the lower end area 17 of the lower part 16 bordering the upper end of the tower, the cross-section of the hollow body 8, which is radial in relation to the tower axis, has a contour that is circle-shaped coaxially to the tower axis. For the radial cross-sections of the hollow body 8 that are positioned above it axially, the circle shape makes a smooth transition into contours that are symmetric to the rotor axis 3 and extended in its direction.

FIG. 4 shows the contour of the connection point 15, which lies in a plane, which extends parallel to the rotor axis 3 and perpendicularly to a plane that is positioned through the rotor axis 3 and the tower axis. The end area of this contour, which faces away from the rotor, has a slightly arched first section 24, which extends crosswise to the rotor axis 3 and is bent rounded off at its ends 25 approximately parallel to the rotor axis 3 in the direction to the end area faces towards the rotor. To the bent ends 25, side sections 26 that are only slightly convexly arched connect in the direction to the end area that faces towards the rotor. These side sections are connected to each other, at the end area that faces towards the rotor, through a second section 27 that is bent towards the first section 24.

It can be seen in FIGS. 1 and 4 that the upper and the lower part 6, 16 each have a flange 28 and/or 28' directed inside at the connection point 15. The end faces of this flange which face each other lie on each other and are clamped together by bolts 29 which are arranged in close series along the flanges 28, 28'. In the embodiment example shown, the flange 28 of the upper part 6 is provided with bore holes 30 going through for the passage of the bolts 29, whereas the flange 28' of the lower part 16 has threaded holes that are equivalent in coverage, in which the bolts 29 are screwed tight.

The contours of the longitudinal sections of the hollow body 8 parallel to the tower axis and the rotor axis 3 run, as can be seen in FIG. 1, in their areas that face away from the rotor, essentially parallel to the tower axis. Such a contour section that runs parallel is indicated in FIG. 1 with the reference indicator 31. In its area that faces towards the rotor, these contours run at a distance to the tower axis increasing from the bottom to the top. The contour section involved is indicated in FIG. 1 with the reference indicator 32.

FIGS. 1 and 2 show especially clearly two elongated supports 33, 33' of I-shaped cross-section, which are affixed on the end of the upper part 6 which faces away from the rotor and extend from there, in the embodiment example shown, approximately parallel to the rotor axis 3 and along a plane radial in relation to the tower axis. The distance between the two supports 33, 33' corresponds approximately to the cross-section measurement of the upper part 6. On these supports 33, 33', the generator 13 is supported via crosswise supports 34, 34' extending crosswise to their longitudinal direction. Furthermore, on the supports 33, 33' if necessary, additional components (not shown) of the wind power plant can be supported.

In the construction of a new wind power plant, usage is made of the structure of the base frame, in particular, in the following manner: Both the upper part 6 including the two supports 33, 33' and the lower part 16 are pre-assembled in the manufacturer's factory, completely or in part, with the components to be allocated to them, in particular, the shaft 1, the gear 2, the generator 13 and the azimuthal drive 20, 23. The two pre-assembled units are transported to the construction site. There, the lower part 16 is lifted onto the tower and connected to its upper end. Then, the upper part 6 is set onto the lower part 16 and screwed down at the connection point 15 with the lower part 16.

Index of Reference Numbers

1	Shaft
2	Hub
3	Rotor axis
4	Receptacle opening
5	Main bearing
6	Upper part
7	Receptacle
8	Hollow body
9	Open edge
10	Bearing block
11	Receptacle
12	Gear
13	Generator
14	Coupling
15	Connection point
16	Lower part
17	Lower end area
18	Radial flange
19	Outer ring
20	Roller bearing
21	Inner ring
22	Drive pinion
23	Servomotor
24	First section
25	End
26	Side sections
27	Second section
28, 28'	Flange
29	Screwed bolts
30	Holes
31	Contour section
32	Contour section
33, 33'	Support
34, 34'	Transverse support

What is claimed is:

1. An apparatus, comprising:

A base frame for the arrangement of a drive train, which is driven by a wind-driven rotor of a wind power plant, on the tower of the wind power plant on which the base frame is affixed with an essentially horizontal orientation of the rotor axis so that it can rotate azimuthally around the essentially vertical axis of the tower and is constructed from a discrete upper part that carries the drive train and a discrete lower part that has an azimuthal drive device that is attachably joined with the upper part at a connection point, wherein the lower part provides for azimuthal rotation around the essentially vertical axis of the tower, wherein the connection point extends along an essentially horizontal cross-section that has a larger dimension in the direction of the rotor axis than in the direction perpendicular to that.

2. The apparatus according to claim 1, wherein the base frame has a hollow body that is radially limited in relation to the tower axis by an essentially closed wall, whereby the cross-sections of this hollow body have, in its lower end area that borders on the upper end of the tower, a circular contour

that, for the cross-sections placed above it axially, makes a transition into a contour that is elongated in the direction of the rotor axis, and the connection point is arranged in the area of its elongated contours.

3. The apparatus according to claim 1, wherein the connection point of both the upper part and the lower part extends in a plane extending parallel to the rotor axis and perpendicularly to the tower axis.

4. The apparatus according to one of the claims 1, 2 or 3, wherein each of the upper part and the lower parts has a flange that is essentially radial in relation to the tower axis in the area of the connection point, and the end faces of the flange which face each other can be clamped together.

5. The apparatus according to claim 4, wherein the upper part and the lower parts can be connected by screwed bolts that pass through the flanges.

6. The apparatus according to one of the claims 3 or 5, wherein one or more elongated contours in the area of the connection point are constructed so that they are symmetrical to the rotor axis and have, at their end area that faces away from the rotor, a first section that extends crosswise to the rotor axis and is bent at its ends in the direction to the end area that faces the rotor, a second section that is located at its end area that faces the rotor and is bent towards the end area that faces away, and two side sections that connect the first section to the second section.

7. The apparatus according to claim 6, wherein the contours of the longitudinal sections of the hollow body parallel to the tower axis and to the rotor axis run essentially parallel to the tower axis in their area that faces away from the rotor and in their area that faces towards the rotor, they run at a distance from the tower axis which increases from the bottom to the top.

8. The apparatus according to one of the claims 1, 2 or 3, wherein a recess for a rotor shaft bearing is constructed in the upper part in its area that faces the rotor.

9. The apparatus according to one of the claims 1, 2 or 3, wherein a recess for the support of a gear is constructed in the upper part in its area that faces away from the rotor.

10. The apparatus according to one of the claims 2 or 3, wherein the lower part has, on its lower end area that borders the upper end of the tower, a flange directed radially to the inside, on which at least one servomotor of the azimuthal drive device is arranged with the drive axis parallel to the tower axis and a pinion gear that is arranged rotationally fixed on the drive axis for combing mesh into an inner crown gear that is affixed on the upper end of the tower coaxially to the tower axis.

11. The apparatus according to claim 10, wherein the inner crown gear is constructed on the inner ring of a roller bearing whose outer ring is affixed to the lower part.

12. The apparatus according to one of the claims 1, 2 or 3, wherein, on the upper part, two supports that extend away from its end that faces away from the rotor essentially in the direction of the rotor axis are arranged, on which at least one generator of the wind power plant can be supported.

13. An apparatus, comprising: A base frame for the arrangement of a drive train, which is driven by a wind-driven rotor of a wind power plant, on the tower of the wind power plant on which the base frame is affixed with an essentially horizontal orientation of the rotor axis so that it can rotate azimuthally around the essentially vertical axis of the tower and is constructed from a discrete upper part that carries the drive train and a discrete lower part that has an azimuthal drive device that is attachably joined with the upper part at a connection point, wherein the lower part provides for azimuthal rotation around the essentially vertical axis of the tower, wherein the connection point extends along an essentially horizontal cross-section that has a larger dimension in the direction of the rotor axis than in the direction perpendicular to that, wherein the base frame has a hollow body that is radially limited in relation to the tower axis by an essentially closed wall, whereby the cross-sections of this hollow body have, in its lower end area that borders on the upper end of the tower, a circular contour that, for the cross-sections placed above it axially, makes a transition into a contour that is elongated in the direction of the rotor axis, and the connection point is arranged in the area of its elongated contours, wherein the elongated contours in the area of the connection point are constructed so that they are symmetrical to the rotor axis and have, at their end area that faces away from the rotor, a first section that extends crosswise to the rotor axis and is bent at its ends in the direction to the end area that faces the rotor, a second section that is located at its end area that faces the rotor and is bent towards the end area that faces away, and two side sections that connect the first section to the second section.

14. The apparatus according to claim 13, wherein the contours of the longitudinal sections of the hollow body parallel to the tower axis and to the rotor axis run essentially parallel to the tower axis in their area that faces away from the rotor and in their area that faces towards the rotor, they run at a distance from the tower axis which increases from the bottom to the top.

15. A base frame for the arrangement of a drive train, which is driven by a wind-driven rotor of a wind power plant, on the tower of the wind power plant on which the base frame is affixed with an essentially horizontal orientation of the rotor axis so that it can rotate azimuthally around the essentially vertical axis of the tower and is constructed from a discrete upper part that carries the drive train and a discrete lower part that has an azimuthal drive device that is attachably joined with the upper part at a connection point, wherein the lower part provides for azimuthal rotation around the essentially vertical axis of the tower, wherein the connection point extends along an essentially horizontal cross-section that has a larger dimension in the direction of the rotor axis than in the direction perpendicular to that, wherein the lower part has, on its lower end area that borders the upper end of the tower, a flange directed radially to the inside, on which at least one servomotor of the azimuthal drive device is arranged with the drive axis parallel to the tower axis and a pinion gear that is arranged rotationally fixed on the drive axis for combing mesh into an inner crown gear that is affixed on the upper end of the tower coaxially to the tower axis.

16. The apparatus according to claim 15, wherein the base frame has a hollow body that is radially limited in relation to the tower axis by an essentially closed wall, whereby the cross-sections of this hollow body have, in its lower end area that borders on the upper end of the tower, a circular contour that, for the cross-sections placed above it axially, makes a transition into a contour that is elongated in the direction of the rotor axis, and the connection point is arranged in the area of its elongated contours.

17. The apparatus according to claim 15, wherein the connection point of both the upper part and the lower part extends in a plane extending parallel to the rotor axis and perpendicularly to the tower axis.

18. The apparatus according to claim 15, wherein the inner crown gear is constructed on the inner ring of a roller bearing whose outer ring is affixed to the lower part.

* * * * *

EXHIBIT B

US007629705B2

(12) United States Patent
Barker et al.

(10) Patent No.: US 7,629,705 B2
(45) Date of Patent: Dec. 8, 2009

(54) **METHOD AND APPARATUS FOR OPERATING ELECTRICAL MACHINES**

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(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 351 days.

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(65) **Prior Publication Data**

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(51) **Int. Cl.**
H02P 11/00 (2006.01)
H02P 9/00 (2006.01)
H02P 9/04 (2006.01)

(52) **U.S. Cl.** 290/55; 322/24; 322/28

(58) **Field of Classification Search** 322/24, 322/28, 44; 290/44, 55
See application file for complete search history.

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(74) *Attorney, Agent, or Firm*—James McGinness, Esq.; Armstrong Teasdale LLP

(57) **ABSTRACT**

A method for operating an electrical machine includes coupling the electrical machine to an electric power system such that the electric power system is configured to transmit at least one phase of electric power to and from the electrical machine. The method also includes configuring the electrical machine such that the electrical machine remains electrically connected to the electric power system during and subsequent to a voltage amplitude of the electric power system operating outside of a predetermined range for an undetermined period of time.

17 Claims, 5 Drawing Sheets

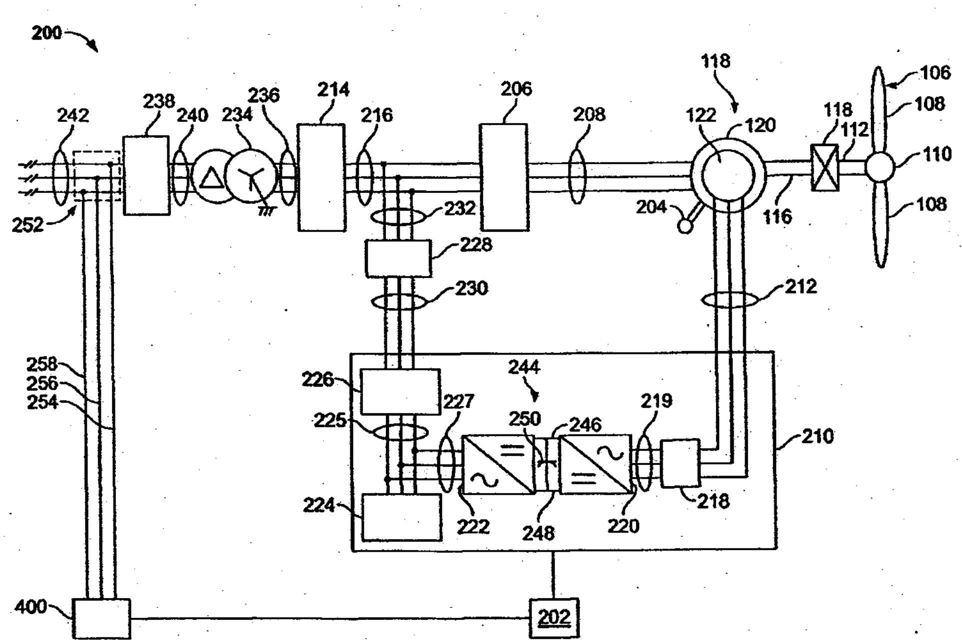

EXHIBIT B

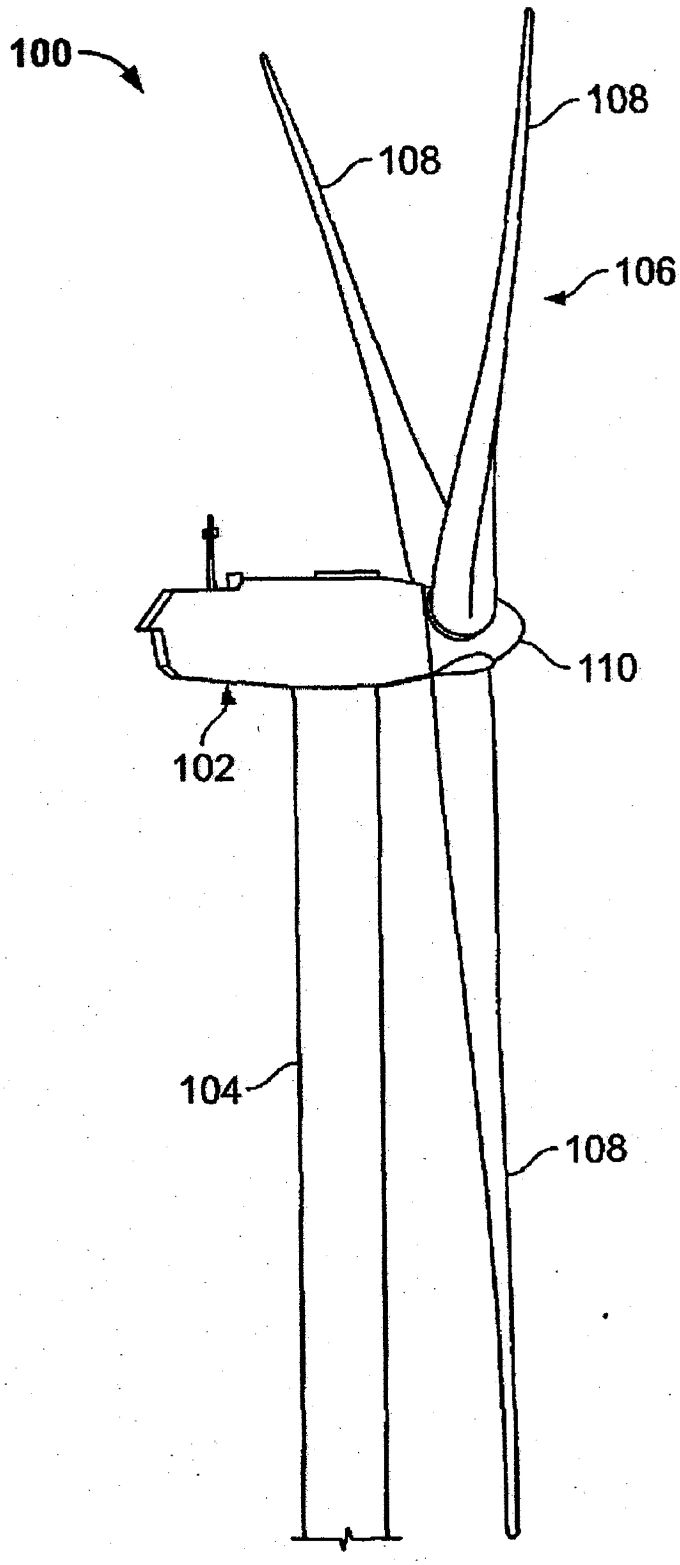

FIG. 1

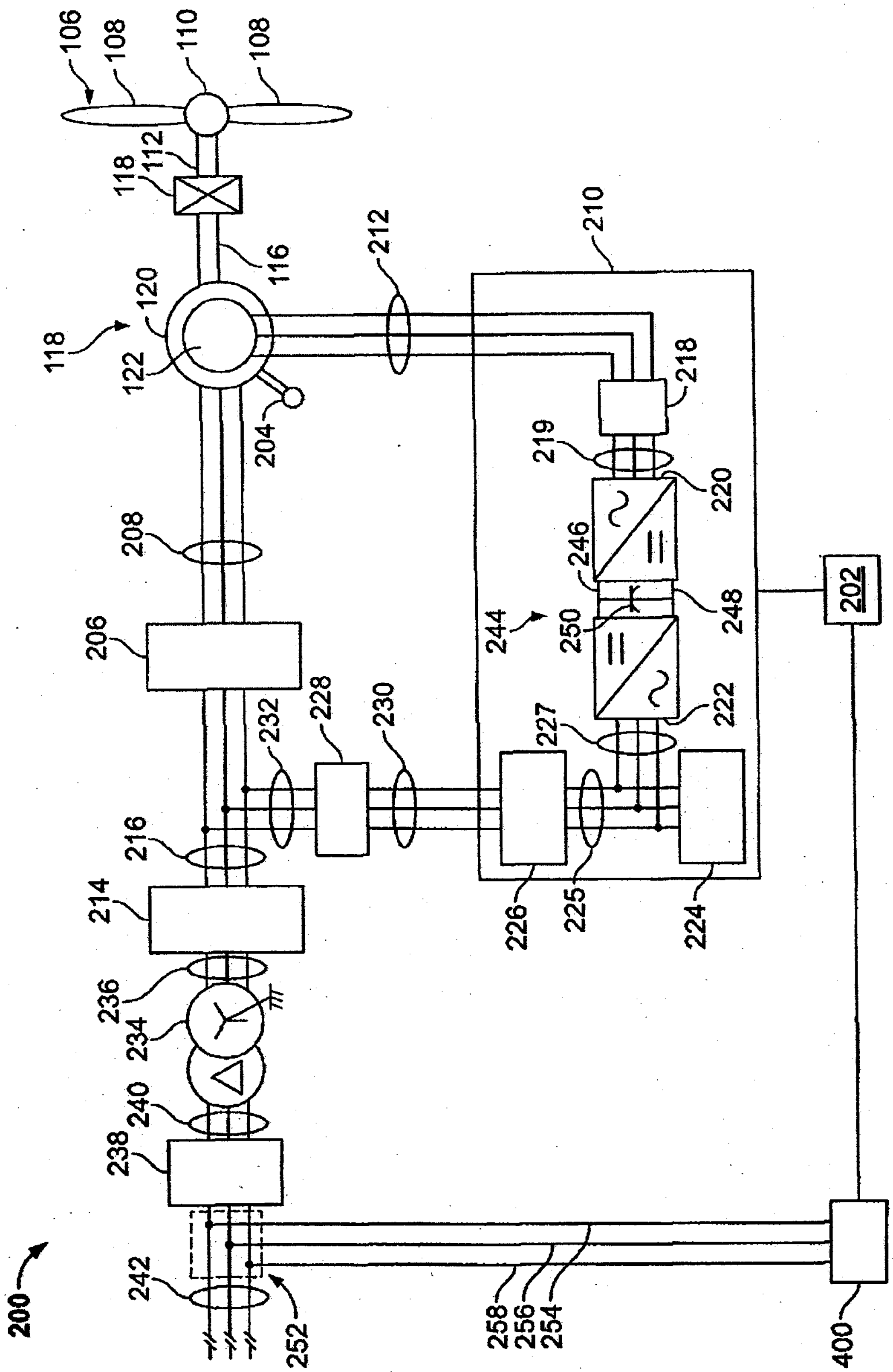

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FIG. 2

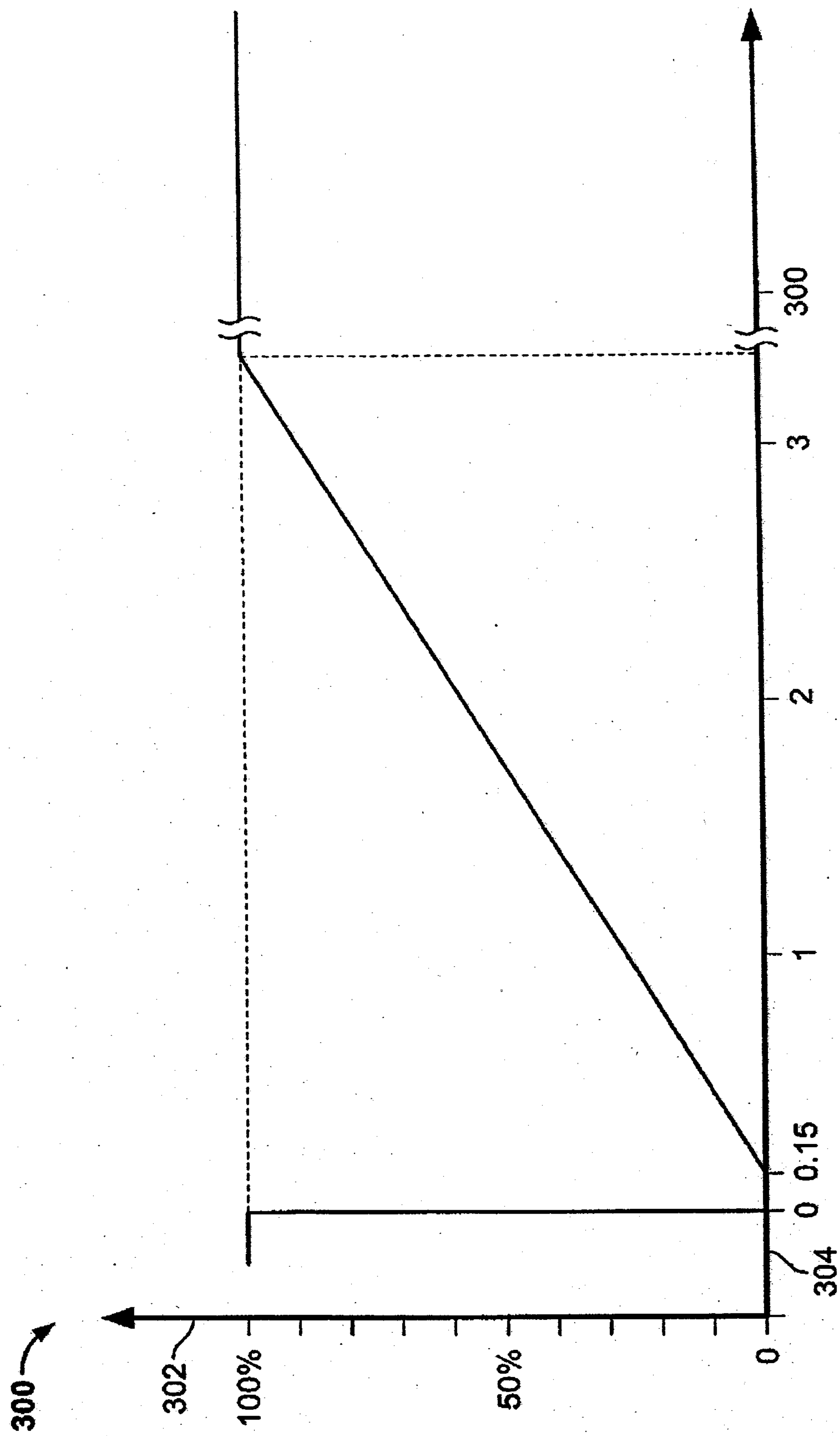
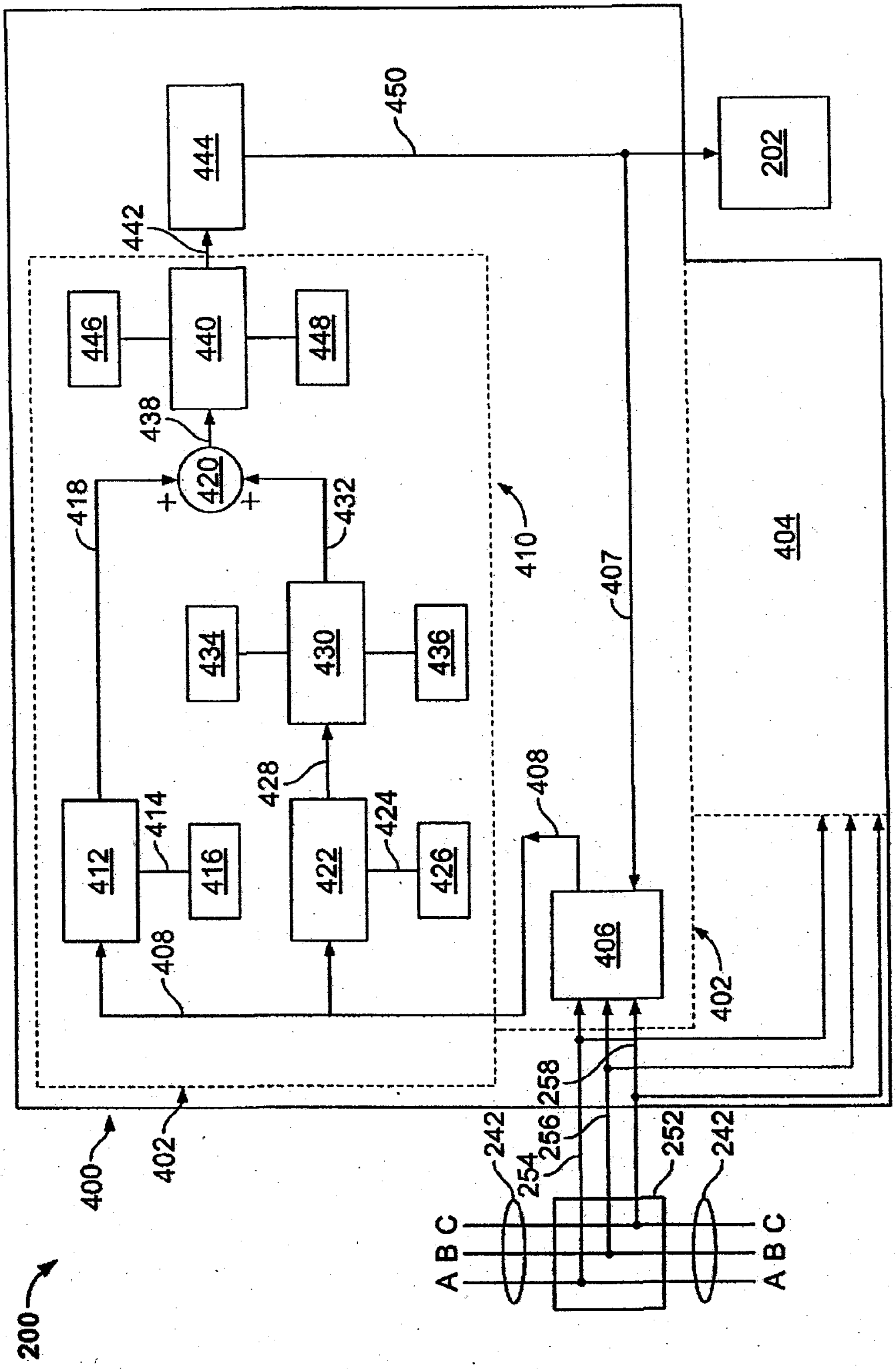


FIG. 3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A B C

FIG. 4

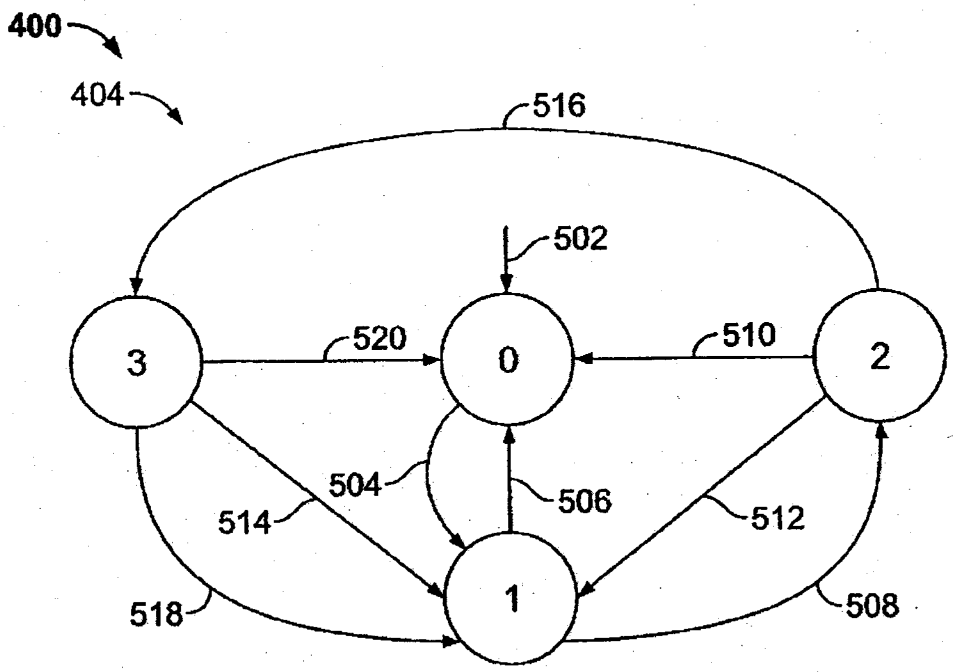

FIG. 5

600

602	604	606	608	610
0	A	C	E	E
1	A	C	F	H
2	B	D	G	I
3	A	C	E	E

FIG. 6

METHOD AND APPARATUS FOR OPERATING ELECTRICAL MACHINES

BACKGROUND OF THE INVENTION

This invention relates generally to electrical machines and more particularly, to methods and apparatus for operating electrical machines.

Generally, a wind turbine generator includes a turbine that has a rotor that includes a rotatable hub assembly having multiple blades. The blades transform mechanical wind energy into a mechanical rotational torque that drives one or more generators via the rotor. The generators are generally, but not always, rotationally coupled to the rotor through a gearbox. The gearbox steps up the inherently low rotational speed of the rotor for the generator to efficiently convert the rotational mechanical energy to electrical energy, which is fed into a utility grid via at least one electrical connection. Gearless direct drive wind turbine generators also exist. The rotor, generator, gearbox and other components are typically mounted within a housing, or nacelle, that is positioned on top of a base that may be a truss or tubular tower.

Some gearless direct drive wind turbine generator configurations include doubly fed induction generators (DFIGs). Such configurations may also include power converters that are used to transmit generator excitation power to a wound generator rotor from one of the connections to the electric utility grid connection. Under certain circumstances, grid voltage fluctuations may be experienced that may include low voltage transients with voltage fluctuations that approach zero volts. Generally, the power converters and the generator are susceptible to grid voltage fluctuations. Therefore, such grid voltage fluctuations may be deleterious to continuous operation of the wind turbine generator.

BRIEF DESCRIPTION OF THE INVENTION

In one aspect, a method for operating an electrical machine is provided. The method includes coupling the electrical machine to an electric power system such that the electric power system is configured to transmit at least one phase of electric power to and from the electrical machine. The method also includes configuring the electrical machine such that the electrical machine remains electrically connected to the electric power system during and subsequent to a voltage amplitude of the electric power system operating outside of a predetermined range for an undetermined period of time.

In another aspect, a control system for an electrical machine is provided. The electrical machine is configured to be electrically coupled to an electric power system. The electric power system is configured to transmit at least one phase of electric power to and from the electrical machine. The control system facilitates the electrical machine remaining electrically connected to the electric power system during and subsequent to at least one voltage amplitude of the electric power operating outside of a predetermined range for an undetermined period of time.

In a further aspect, a wind turbine is provided. The wind turbine includes at least one electric power generator configured to be electrically coupled to an electric power system. The electric power system is configured to transmit at least one phase of electric power to and from the generator. The wind turbine also includes at least one control system configured to be electrically coupled to the electric power system. The control system facilitates the electrical machine remaining electrically connected to the electric power system during and subsequent to at least one voltage amplitude of the electric power operating outside of a predetermined range for an undetermined period of time.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** is a schematic view of an exemplary wind turbine generator;

FIG. **2** is a schematic view of an exemplary electrical and control system that may be used with the wind turbine generator shown in FIG. **1**;

FIG. **3** is a graphical view of grid line voltage versus time that may be associated with the electrical and control system shown in FIG. **2**;

FIG. **4** is a block diagram view of an exemplary phase-locked loop (PLL) regulator that may be used with the electrical and control system shown in FIG. **2**;

FIG. **5** is a block diagram view of an exemplary PLL state machine that may be used with the PLL regulator shown in FIG. **4**; and

FIG. **6** is a tabular view of a plurality of exemplary gain constant and frequency limit values generated as a function of PLL state as determined by the PLL state machine shown in FIG. **5**.

DETAILED DESCRIPTION OF THE INVENTION

FIG. **1** is a schematic view of an exemplary wind turbine generator **100**. The wind turbine **100** includes a nacelle **102** housing a generator (not shown in FIG. **1**). Nacelle **102** is mounted on a tower **104** (a portion of tower **104** being shown in FIG. **1**). Tower **104** may be any height that facilitates operation of wind turbine **100** as described herein. Wind turbine **100** also includes a rotor **106** that includes three rotor blades **108** attached to a rotating hub **110**. Alternatively, wind turbine **100** includes any number of blades **108** that facilitate operation of wind turbine **100** as described herein. In the exemplary embodiment, wind turbine **100** wind turbine **100** includes a gearbox (not shown in FIG. **1**) rotatingly coupled to rotor **106** and a generator (not shown in FIG. **1**).

FIG. **2** is a schematic view of an exemplary electrical and control system **200** that may be used with wind turbine generator **100** (shown in FIG. **1**). Rotor **106** includes plurality of rotor blades **108** coupled to rotating hub **110**. Rotor **106** also includes a low-speed shaft **112** rotatably coupled to hub **110**. Low-speed shaft is coupled to a step-up gearbox **114**. Gearbox **114** is configured to step up the rotational speed of low-speed shaft **112** and transfer that speed to a high-speed shaft **116**. In the exemplary embodiment, gearbox **114** has a step-up ratio of approximately 70:1. For example, low-speed shaft **112** rotating at approximately 20 revolutions per minute (20) coupled to gearbox **114** with an approximately 70:1 step-up ratio generates a high-speed shaft **116** speed of approximately 1400 rpm. Alternatively, gearbox **114** has any step-up ratio that facilitates operation of wind turbine **100** as described herein. Also, alternatively, wind turbine **100** includes a direct-drive generator wherein a generator rotor (not shown in FIG. **1**) is rotatingly coupled to rotor **106** without any intervening gearbox.

High-speed shaft **116** is rotatably coupled to generator **118**. In the exemplary embodiment, generator **118** is a wound rotor, synchronous, 60 Hz, three-phase, doubly-fed induction generator (DFIG) that includes a generator stator **120** magnetically coupled to a generator rotor **122**. Alternatively, generator **118** is any generator that facilitates operation of wind turbine **100** as described herein.

Electrical and control system **200** includes a controller **202**. Controller **202** includes at least one processor and a memory, at least one processor input channel, at least one processor output channel, and may include at least one computer (none shown in FIG. **2**). As used herein, the term computer is not limited to just those integrated circuits referred to in the art as a computer, but broadly refers to a processor, a microcontroller, a microcomputer, a programmable logic controller (PLC), an application specific integrated circuit, and other programmable circuits (none shown in FIG. **2**), and these terms are used interchangeably herein. In the exemplary embodiment, memory may include, but is not limited to, a computer-readable medium, such as a random access memory (RAM) (none shown in FIG. **2**). Alternatively, a floppy disk, a compact disc—read only memory (CD-ROM), a magneto-optical disk (MOD), and/or a digital versatile disc (DVD) (none shown in FIG. **2**) may also be used. Also, in the exemplary embodiment, additional input channels (not shown in FIG. **2**) may be, but not be limited to, computer peripherals associated with an operator interface such as a mouse and a keyboard (neither shown in FIG. **2**). Alternatively, other computer peripherals may also be used that may include, for example, but not be limited to, a scanner (not shown in FIG. **2**). Furthermore, in the exemplary embodiment, additional output channels may include, but not be limited to, an operator interface monitor (not shown in FIG. **2**).

Processors for controller **202** process information transmitted from a plurality of electrical and electronic devices that may include, but not be limited to, speed and power transducers. RAM and storage device store and transfer information and instructions to be executed by the processor. RAM and storage devices can also be used to store and provide temporary variables, static (i.e., non-changing) information and instructions, or other intermediate information to the processors during execution of instructions by the processors. Instructions that are executed include, but are not limited to, resident conversion and/or comparator algorithms. The execution of sequences of instructions is not limited to any specific combination of hardware circuitry and software instructions.

Electrical and control system **200** also includes generator rotor tachometer **204** that is coupled in electronic data communication with generator **118** and controller **202**. Generator stator **120** is electrically coupled to a stator synchronizing switch **206** via a stator bus **208**. In the exemplary embodiment, to facilitate the DFIG configuration, generator rotor **122** is electrically coupled to a bi-directional power conversion assembly **210** via a rotor bus **212**. Alternatively, system **200** is configured as a full power conversion system (not shown) known in the art, wherein a fill power conversion assembly (not shown) that is similar in design and operation to assembly **210** is electrically coupled to stator **120** and such full power conversion assembly facilitates channeling electrical power between stator **120** and an electric power transmission and distribution grid (not shown). Stator bus **208** transmits three-phase power from stator **120** and rotor bus **212** transmits three-phase power from rotor **122** to assembly **210**. Stator synchronizing switch **206** is electrically coupled to a main transformer circuit breaker **214** via a system bus **216**.

Assembly **210** includes a rotor filter **218** that is electrically coupled to rotor **122** via rotor bus **212**. Rotor filter **218** is electrically coupled to a rotor-side, bi-directional power converter **220** via a rotor filter bus **219**. Converter **220** is electrically coupled to a line-side, bi-directional power converter **222**. Converters **220** and **222** are substantially identical. Power converter **222** is electrically coupled to a line filter **224** and a line contactor **226** via a line-side power converter bus **223** and a line bus **225**. In the exemplary embodiment, converters **220** and **222** are configured in a three-phase, pulse width modulation (PWM) configuration including insulated gate bipolar transistor (IGBT) switching devices (not shown in FIG. **2**) that "fire" as is known in the art. Alternatively, converters **220** and **222** have any configuration using any switching devices that facilitate operation of system **200** as described herein. Assembly **210** is coupled in electronic data communication with controller **202** to control the operation of converters **220** and **222**.

Line contactor **226** is electrically coupled to a conversion circuit breaker **228** via a conversion circuit breaker bus **230**. Circuit breaker **228** is also electrically coupled to system circuit breaker **214** via system bus **216** and connection bus **232**. System circuit breaker **214** is electrically coupled to an electric power main transformer **234** via a generator-side bus **236**. Main transformer **234** is electrically coupled to a grid circuit breaker **238** via a breaker-side bus **240**. Grid breaker **238** is connected to an electric power transmission and distribution grid via a grid bus **242**.

In the exemplary embodiment, converters **220** and **222** are coupled in electrical communication with each other via a single direct current (DC) link **244**. Alternatively, converters **220** and **222** are electrically coupled via individual and separate DC links (not shown in FIG. **2**). DC link **244** includes a positive rail **246**, a negative rail **248**, and at least one capacitor **250** coupled therebetween. Alternatively, capacitor **250** is one or more capacitors configured in series or in parallel between rails **246** and **248**.

System **200** further includes a phase-locked loop (PLL) regulator **400** that is configured to receive a plurality of voltage measurement signals from a plurality of voltage transducers **252**. In the exemplary embodiment) each of three voltage transducers **252** are electrically coupled to each one of the three phases of bus **242**. Alternatively, voltage transducers **252** are electrically coupled to system bus **216**. Also, alternatively, voltage transducers **252** are electrically coupled to any portion of system **200** that facilitates operation of system **200** as described herein. PLL regulator **400** is coupled in electronic data communication with controller **202** and voltage transducers **252** via a plurality of electrical conduits **254**, **256**, and **258**. Alternatively, PLL regulator **400** is configured to receive any number of voltage measurement signals from any number of voltage transducers **252**, including, but not limited to, one voltage measurement signal from one voltage transducer **252**. PLL regulator **400** is discussed further below.

During operation, wind impacts blades **108** and blades **108** transform mechanical wind energy into a mechanical rotational torque that rotatingly drives low-speed shaft **112** via hub **110**. Low-speed shaft **112** drives gearbox **114** that subsequently steps up the low rotational speed of shaft **112** to drive high-speed shaft **116** at an increased rotational speed. High speed shaft **116** rotatingly drives rotor **122**. A rotating magnetic field is induced within rotor **122** and a voltage is induced within stator **120** that is magnetically coupled to rotor **122**. Generator **118** converts the rotational mechanical energy to a sinusoidal, three-phase alternating current (AC) electrical energy signal in stator **120**. The associated electrical power is transmitted to main transformer **234** via bus **208**, switch **206**, bus **216**, breaker **214** and bus **236**. Main transformer **234** steps up the voltage amplitude of the electrical power and the transformed electrical power is further transmitted to a grid via bus **240**, circuit breaker **238** and bus **242**.

In the doubly-fed induction generator configuration, a second electrical power transmission path is provided. Electrical,

three-phase, sinusoidal, AC power is generated within wound rotor 122 and is transmitted to assembly 210 via bus 212. Within assembly 210, the electrical power is transmitted to rotor filter 218 wherein the electrical power is modified for the rate of change of the PWM signals associated with converter 220. Converter 220 acts as a rectifier and rectifies the sinusoidal, three-phase AC power to DC power. The DC power is transmitted into DC link 244. Capacitor 250 facilitates mitigating DC link 244 voltage amplitude variations by facilitating mitigation of a DC ripple associated with AC rectification.

The DC power is subsequently transmitted from DC link 244 to power converter 222 wherein converter 222 acts as an inverter configured to convert the DC electrical power from DC link 244 to three-phase, sinusoidal AC electrical power with pre-determined voltages, currents, and frequencies. This conversion is monitored and controlled via controller 202. The converted AC power is transmitted from converter 222 to bus 216 via buses 227 and 225, line contactor 226, bus 230, circuit breaker 228, and bus 232. Line filter 224 compensates or adjusts for harmonic currents in the electric power transmitted from converter 222. Stator synchronizing switch 206 is configured to close such that connecting the three-phase power from stator 120 with the three-phase power from assembly 210 is facilitated.

Circuit breakers 228, 214, and 238 are configured to disconnect corresponding buses, for example, when current flow is excessive and can damage the components of the system 200. Additional protection components are also provided, including line contactor 226, which may be controlled to form a disconnect by opening a switch (not shown in FIG. 2) corresponding to each of the lines of the line bus 230.

Assembly 210 compensates or adjusts the frequency of the three-phase power from rotor 122 for changes, for example, in the wind speed at hub 110 and blades 108. Therefore, in this manner, mechanical and electrical rotor frequencies are decoupled and the electrical stator and rotor frequencies matching is facilitated substantially independently of the mechanical rotor speed.

Under some conditions, the bi-directional characteristics of assembly 210, and specifically, the bi-directional characteristics of converters 220 and 222, facilitate feeding back at least some of the generated electrical power into generator rotor 122. More specifically, electrical power is transmitted from bus 216 to bus 232 and subsequently through circuit breaker 228 and bus 230 into assembly 210. Within assembly 210, the electrical power is transmitted through line contactor 226 and busses 225 and 227 into power converter 222. Converter 222 acts as a rectifier and rectifies the sinusoidal, three-phase AC power to DC power. The DC power is transmitted into DC link 244. Capacitor 250 facilitates mitigating DC link 244 voltage amplitude variations by facilitating mitigation of a DC ripple sometimes associated with three-phase AC rectification.

The DC power is subsequently transmitted from DC link 244 to power converter 220 wherein converter 220 acts as an inverter configured to convert the DC electrical power transmitted from DC link 244 to a three-phase, sinusoidal AC electrical power with pre-determined voltages, currents, and frequencies. This conversion is monitored and controlled via controller 202. The converted AC power is transmitted from converter 220 to rotor filter 218 via bus 219 is subsequently transmitted to rotor 122 via bus 212. In this manner, generator reactive power control is facilitated.

Assembly 210 is configured to receive control signals from controller 202. The control signals are based on sensed conditions or operating characteristics of wind turbine 100 and

system 200 as described herein and used to control the operation of the power conversion assembly 210. For example, tachometer 204 feedback in the form of sensed speed of the generator rotor 122 may be used to control the conversion of the output power from rotor bus 212 to maintain a proper and balanced three-phase power condition. Other feedback from other sensors also may be used by system 200 to control assembly 210 including, for example, stator and rotor bus voltages and current feedbacks. Using this feedback information, and for example, switching control signals, stator synchronizing switch control signals and system circuit breaker control (trip) signals may be generated in any known manner. For example, for a grid voltage transient with predetermined characteristics, controller 202 will at least temporarily substantially suspend firing of the IGBTs within converter 222. Such suspension of operation of converter 222 will substantially mitigate electric power being channeled through conversion assembly 210 to approximately zero.

FIG. 3 is a graphical view of grid line voltage versus time 300 that may be associated with electrical and control system 200 (shown in FIG. 2). Graph 300 includes an ordinate (y-axis) 302 that represents grid line voltage in units of percent (%). Y-axis 302 illustrates 0% at the graph origin and extends up to 100%. A grid line voltage of 0% is indicative of zero voltage on bus 242 (shown in FIG. 2). A grid line voltage of 100% indicates a voltage on bus 242 that is 100% of the nominal pre-determined voltage associated with system 200. Graph 300 also includes an abscissa (x-axis) 304 that represents time in seconds (s). A zero voltage transient is illustrated to start at time equals 0 seconds. In the exemplary embodiment, the zero voltage condition on bus 242 is 0.15 seconds wherein the voltage on bus 242 fully recovers to 100% at approximately 3.5 seconds after the initiation of the transient. Alternatively, a length of time of the zero voltage condition and the characteristics of a grid voltage recovery depend upon a variety of factors known in the art.

When the voltage decreases to zero as illustrated in FIG. 3, it is likely that there are faults that prevent wind turbine generator 100 from transmitting electrical power to the grid. In the event that the wind continues to rotate rotor 106 (shown in FIGS. 1 and 2), wind turbine generator 100 continues to generate energy that is not converted to electrical energy. Instead, the energy accelerates rotor 106 until a trip feature is initiated that includes, but is not limited to, a manual trip or an automated overspeed trip.

Moreover, generally, power converter assembly 210 and generator 118 (both shown in FIG. 2) are susceptible to grid voltage fluctuations. Generator 118 may store magnetic energy that can be converted to high currents when a generator terminal voltage decreases quickly. Those currents can mitigate life expectancies of components of assembly 210 that may include, but not be limited to, semiconductor devices such as the IGBTs within converters 220 and 222 (both shown in FIG. 2).

FIG. 4 is a block diagram view of exemplary phase-locked loop (PLL) regulator 400 that may be used with electrical and control system 200. PLL regulator 400 is configured to facilitate a zero voltage ride through (ZVRT) capability for wind turbine generator 100 such that a potential for a wind turbine generator trip and associated consequences to the semiconductor devices are mitigated during zero voltage transients such as that illustrated in FIG. 3. ZVRT is contrasted to low voltage ride through (LVRT) features known in the art that facilitate mitigating wind turbine generator 100 trips during transients wherein the voltage amplitude rapidly decreases, yet does not decrease to zero volts.

PLL regulator **400** is coupled in electronic data communication with plurality of voltage transducers **252** via electrical conduits **254**, **256**, and **258** for phases A, B and C of grid bus **242**. In the exemplary embodiment, conduits **254**, **256** and **258** are electrical cables. Alternatively, a network of transmitters and receivers operating in a pre-determined portion of a radio frequency (RF) band may be used to define conduits **254**, **256** and **258**. Sinusoidal voltage measurement signals are transmitted from voltage transducers **252** through conduits **254**, **256**, and **258** for each of the three phases A, B and C, respectively.

In the exemplary embodiment, PLL regulator **400** is configured as a plurality of function blocks within a processor (not shown in FIG. 4). For clarity, PLL regulator **400** is illustrated external to controller **202**. Alternatively, PLL regulator **400** is configured within a processor associated with controller **202**.

PLL regulator **400** includes at least one phase-locked loop (PLL) **402**. Typically, a PLL is a closed-loop feedback scheme that maintains signals generated by the PLL in a fixed phase relationship with a reference signal. The PLL-generated signal is constantly adjusted to match, in phase, the frequency of the reference signal, i.e., the PLL "locks on" to the reference signal. In the exemplary embodiment, PLL **402** locks on to the frequency of bus **242**. PLL regulator **400** also includes at least one PLL state machine **404** which is described in further detail below.

PLL **402** includes a phase detector function block **406** that is configured to receive the sinusoidal voltage measurement signals transmitted from conduits **254**, **256** and **258** for A-phase, B-phase and C-phase of grid bus **242**, respectively. Function block **406** is also configured to receive a phase angle feedback signal **407** and subsequently combines the voltage measurement signals with signal **407** to a generate phase error signal **408**. Signal **408** is typically measured in radians (r).

PLL **402** also includes a proportional-integral (PI) filter **410**. PI filter **410** includes a proportional gain function block **412**. Function block **412** is configured to receive signal **408**. Function block **412** is also configured to receive a proportional gain constant signal **414** from a proportional gain constant register **416**. Register **416** is populated with values determined as a function of a PLL state (or, PLL mode) as determined by PLL state machine **404** described below. Function block **412** is further configured to multiply signal **408** by signal **414** to generate a proportional gain signal **418** and to transmit signal **418** to a summation function block **420**. Signal **418** is typically measured in r/s.

PI filter **410** also includes an integral gain function block **422**. Function block **422** is configured to receive signal **408**. Function block **422** is also configured to receive an integral gain constant signal **424** from an integral gain constant register **426**. Register **426** is populated with values determined as a function of a PLL state (or, PLL mode) as determined by PLL state machine **404** described below. Function block **422** is further configured to integrate signal **408** with respect to time and multiply the integral value by signal **424** to generate and transmit an integral gain signal **428** to a clamping function block **430**. Signal **428** is typically measured in r/s. Function block **430** is a filter mechanism that permits a clamped integral gain signal **432** to transmit to summation function block **420** if signal **428** resides between a high limit and a low limit. Signal **432** is typically measured in r/s. In contrast, if signal **428** resides outside of a range defined by the high and low limits, signal **428** is blocked from further transmission. The high and low limits of function block **430** are transmitted to and populated within a high limit register **434** and a low limit register **436**, respectively, with values determined as a function of a PLL state (or, PLL mode) as determined by PLL state machine **404** described below.

Function block **420** sums signals **418** and **432** to generate a PI signal **438** and transmit signal **438** to a clamping function block **440**. Signal **438** is typically measured in r/s. Function block **440** is a filter mechanism that permits a clamped integral gain signal **442** to transmit to an integrating function block **444** if signal **438** resides between a high limit and a low limit. Signal **442** is typically measured in r/s. In contrast, if signal **438** resides outside of the range defined by the high and low limits, signal **438** is blocked from further transmission. The high and low limits of function block **440** are transmitted to and populated within a high limit register **446** and a low limit register **448** with values determined as a function of a PLL state (or, PLL mode) as determined by PLL state machine **404** described below.

Integrating function block **444** is configured to receive signal **442** and to integrate signal **444** with respect to time. Function block **444** generates a PLL phase angle signal **450** that is transmitted to controller **202** for control of assembly **210** for subsequent control of electrical currents injected into bus **216** (both shown in FIG. 2). Feedback signal **407** is identical to signal **450** and is transmitted to function block **406** as described above. Signals **450** and **407** are typically measured in radians (r).

The grid voltage measurement signals are also transmitted to PLL state machine **404** from transducers **252** to be used as described below.

A method for operating generator **118** is provided. The method includes coupling generator **118** to the grid such that the grid is configured to transmit at least one phase of electric power to and from generator **118**. The method also includes configuring generator **118** such that the generator **118** remains electrically connected to the electric power system during and subsequent to a voltage amplitude of the electric power system operating outside of a predetermined range for an undetermined period of time. Specifically, such method includes configuring generator **118** such that generator **118** remains electrically connected to the grid during and subsequent to a voltage amplitude of the electric power decreasing to approximately zero volts for a predetermined period of time, thereby facilitating zero voltage ride through (ZVRT). Moreover, facilitating generator **118** to remain electrically connected to the grid during a ZVRT event subsequently facilitates generator **118** continuing to operate thereby supporting the grid during the transient.

Specifically, FIG. 5 is a block diagram view of exemplary PLL state machine **404** that may be used with PLL regulator **400** (shown in FIG. 4). In the exemplary embodiment, state machine **404** is configured to transfer PLL regulator **400** to at least one of four states, or modes, of operation as a function of characteristics of voltage signals received as described above. Alternatively, PLL state machine **404** and PLL regulator **400** includes any number of states that facilitates operation of wind turbine **100** as described herein. Each change of state of operation facilitates a dynamic switching between aggressive and non-aggressive gain constants and non-restrictive and restrictive clamps contained within registers **416**, **426**, **434**, **436**, **446** and **448** (all shown in FIG. 4). Such switching may be configured to be sliding in nature, discrete in nature, or some combination thereof. Therefore, the plurality of states of operation facilitate zero voltage ride through (ZVRT) as well as other grid faults while also facilitating normal operation. These features facilitate managing such gains and clamps dynamically as a function of the voltage characteristics of the grid to which PLL **402** (shown in FIG. 4) is attempting to lock on to and/or stay locked on to.

State machine 404 is configured to receive the grid voltage measurement signals transmitted to PLL regulator 400 from transducers 252 via conduits 254, 256 and 258 (all shown in FIG. 4). State machine 404 is further configured to receive a "power up" input signal 502 upon successful powering up of PLL regulator 400. Receipt of input signal 502 initiates state machine 404 shifting to state 0. State 0 is characterized by state machine 404 preconditioning a set of values to be inserted into registers 416, 426, 434, 436, 446 and 448.

FIG. 6 is a tabular view of a plurality of exemplary gain and frequency limit values 600 generated as a function of PLL state as determined by PLL state machine 404 (shown in FIG. 5). Column 602 represents a plurality of rows 0, 1, 2 and 3 that each correspond to a state of operation of PLL regulator 400 (shown in FIG. 5). PLL regulator 400 may be in only one state of operation at any one time. Column 604 represents a plurality of gain constant values that may be stored in register 416 (shown in FIG. 4). Column 606 represents a plurality of gain constant values that may be stored in register 426 (shown in FIG. 4). Column 606 represents a plurality of minimum frequency limit values that may be stored in registers 436 and 448. Column 608 represents a plurality of maximum frequency limit values that may be stored in registers 434 and 446. For example, when PLL regulator 400 is in state 0 gain values A and C are in registers 416 and 426, respectively. In the exemplary embodiment, values A and C represent differing numerical values, for example, but not being limited to, 2.46737 and 328.039, respectively. Moreover, in state 0, value E is in registers 436, 448, 434, and 446. In the exemplary embodiment, value E represents a numerical value, for example, but not being limited to, 376.99. Alternatively, differing numerical values that facilitate operation of system 200 as described herein may be in registers 436, 448, 434, and 446.

Referring to FIG. 5, in the exemplary embodiment, after a pre-determined period of time (normally a few seconds), state machine 404 attains a permissive to shift regulator 400 to state 1. Upon successful synchronization of wind turbine generator 100 to the grid, as determined by a closing of circuit breaker 238 for example, state machine 404 shifts regulator 400 to state 1 via a transition path 504. Alternatively, any conditions that facilitate operation of system 200 as described herein may be used. Moreover, upon de-synchronization of wind turbine generator 100 from the grid, as determined for example by an opening of circuit breaker 238, state machine 404 shifts regulator 400 to state 0 from state 1 via transition path 506.

Referring to FIG. 6, when PLL regulator 400 is in state 1 gain values A and C are in registers 416 and 426, respectively. In the exemplary embodiment, values A and C represent differing numerical values, for example, but not being limited to, 2.46737 and 328.039, respectively. Moreover, in state 1, value F is in registers 436 and 448, and value H is in registers 434 and 446. In the exemplary embodiment, values F and H represents differing numerical values, for example, but not being limited to, −1507.96 and 1884.96, respectively. Alternatively, differing numerical values that facilitate operation of system 200 as described herein may be in registers 436, 448, 434, and 446. Values A and C are sometimes referred to as "hot" values and values F and H are sometimes referred to as "wide" values. Such values facilitate PLL 402 initially locking on to the grid frequency.

Referring to FIG. 5, in the exemplary embodiment, after a pre-determined period of time after PLL 402 locks on to the grid frequency, state machine 404 shifts regulator 400 to state 2 via a transition path 508. Alternatively, any conditions that facilitate operation of system 200 as described herein may be used. Upon de-synchronization of wind turbine generator 100 from the grid, as determined for example by an opening of circuit breaker 238, state machine 404 shifts regulator 400 to state 0 from state 2 via transition path 510.

Referring to FIG. 6, when PLL regulator 400 is in state 2 gain values B and D are in registers 416 and 426, respectively. In the exemplary embodiment, values B and D represent differing numerical values, for example, but not being limited to, 0.039937 and 0.393601, respectively. Moreover, in state 2, value G is in registers 436 and 448, and value I is in registers 434 and 446. In the exemplary embodiment, values G and I represent differing numerical values, for example, but not being limited to, 94.2478 and 502.529, respectively. Alternatively, differing numerical values that facilitate operation of system 200 as described herein may be in registers 436, 448, 434, and 446. Values B and D are sometimes referred to as "cool" values and values G and I are sometimes referred to as "narrow" values. Such values facilitate PLL 402 adjusting to frequency transients on the grid more slowly than in state 1. This feature facilitates a sluggish reaction of system 200 to normal, minor fluctuations of grid voltage conditions. Moreover, such values facilitate a state shift for more sever grid disturbances as discussed further below. Under normal circumstances, a majority of the time that wind turbine generator 100 is synchronized to the grid, regulator 400 is in state 2.

Referring to FIG. 5, in the exemplary embodiment, in the event of a non-synchronous grid fault, abnormally low (not zero) and/or high grid voltage amplitudes, and/or PLL phase error signal 450 (shown in FIG. 4) exceeds a predetermined threshold, state machine 404 shifts regulator 400 to state 1 from state 2 via a transition path 512. Alternatively, any conditions that facilitate operation of system 200 as described herein may be used. While in state 1, the appropriate gain and clamp values are in the appropriate registers as described above. Upon restoration of the grid voltage to per-determined values, after a pre-determined period of time after PLL 402 locks on to the grid frequency, and PLL error signal 450 remains under a pre-determined threshold for a pre-determined period of time, state machine 404 shifts regulator 400 to state 2 from state 1 via transition path 508. While in state 2, the appropriate gain and clamp values are in the appropriate registers as described above and LVRT is facilitated.

While regulator 400 is in state 1, a shift to a state 3 may occur via transition path 514. Similarly, while regulator 400 is in state 2, a shift to state 3 from state 2 via transition path 516 may occur. In the exemplary embodiment, the pre-requisites to shift from states 1 and 2 to state 3 includes a grid voltage disturbance that is associated with a symmetric fault that decreases grid voltage to zero volts. Referring to FIG. 6, when PLL regulator 400 is in state 3 gain values A and C are in registers 416 and 426, respectively. In the exemplary embodiment, values A and C represent differing numerical values, for example, but not being limited to, 2.46737 and 328.039, respectively. Moreover, in state 3, value E is in registers 436, 448, 434, and 446. In the exemplary embodiment, value E represents a numerical value, for example, but not being limited to, 376.99. Alternatively, differing numerical values that facilitate operation of system 200 as described herein may be in registers 436, 448, 434, and 446. These values facilitate PLL phase angle signal 450 being driven to a phase angle value that would be in effect if there was no grid disturbance. This further facilitates PLL 402 being driven to oscillate at a pre-determined frequency that is substantially similar to the nominal operating frequency, for example, but not being limited to, 60 Hz. Under these circumstances, a potential for wind turbine generator trip is mitigated and ZVRT is facilitated.

Referring to FIG. **5**, upon restoration of grid voltage, regulator **400** shifts from state **3** to state **1** via transition path **518**. Alternatively, any conditions that facilitate operation of system **200** as described herein may be used. While in state **1**, the appropriate gain and clamp values are in the appropriate registers as described above. Upon restoration of the grid voltage to per-determined values, after a pre-determined period of time after PLL **402** locks on to the grid frequency, and PLL error signal **450** remains under a pre-determined threshold for a pre-determined period of time, state machine **404** shifts regulator **400** to state **2** from state **1** via transition path **508**. While in state **2**, the appropriate gain and clamp values are in the appropriate registers as described above. Shifting from state **3** to state **1** and then state **2** facilitates effecting smooth state shifting. Upon de-synchronization of wind turbine generator **100** from the grid, as determined for example by an opening of circuit breaker **238**, state machine **404** shifts regulator **400** to state **0** from state **3** via transition path **520**.

The method and apparatus for a wind turbine generator control system described herein facilitate operation of a wind turbine generator. More specifically, the wind turbine generator electrical and control system as described above facilitates an efficient and effective electrical generation and mechanical load transfer scheme. Also, the robust, electrical and control system facilitates generator production efficiency and effectiveness. Such control system also facilitates wind turbine generator reliability and wind turbine generator outages by reducing the number of trips due to grid disturbances.

Exemplary embodiments of wind turbine electrical and control systems as associated with wind turbine generators are described above in detail. The methods, apparatus and systems are not limited to the specific embodiments described herein nor to the specific illustrated wind turbine generators.

While the invention has been described in terms of various specific embodiments, those skilled in the art will recognize that the invention can be practiced with modification within the spirit and scope of the claims.

What is claimed is:

1. A method for operating an electrical machine, said method comprising:

coupling the electrical machine to an electric power system such that the electric power system is configured to transmit at least one phase of electric power to the electrical machine; and

configuring the electrical machine such that the electrical machine remains electrically connected to the electric power system during and subsequent to a voltage amplitude of the electric power system operating outside of a predetermined range for an undetermined period of time, said configuring the electrical machine comprising:

electrically coupling at least a portion of a control system to at least a portion of the electric power system;

coupling the control system in electronic data communication with at least a portion of the electrical machine; and

configuring the electrical machine and the control system such that the electrical machine remains electrically connected to the electric power system during and subsequent to the voltage amplitude of the electric power system decreasing below the predetermined range including approximately zero volts for the undetermined period of time, thereby facilitating zero voltage ride through (ZRVT).

2. A method in accordance with claim **1** wherein coupling the control system in electronic data communication with at least a portion of the electrical machine comprises:

providing a phase-locked loop (PLL) regulator within the control system that has a PLL in electronic data communication with a PLL state machine;

measuring a voltage of the electric power in the electric power system;

generating a voltage measurement signal and a frequency measurement signal;

transmitting the voltage measurement signal to the PLL state machine;

transmitting the frequency measurement signal to the PLL;

determining a PLL regulator state;

using at least one algorithm within the PLL to generate at least one electrical machine control signal;

coupling a power conversion assembly to at least a portion of the control system and to at least a portion of the electrical machine;

coupling the control system to at least a portion of the power conversion assembly; and

configuring at least a portion of the control system to mitigate channeling electrical power through the power conversion assembly.

3. A method in accordance with claim **2** wherein determining a PLL regulator state comprises the PLL state machine:

receiving the voltage measurement signal;

using at least one algorithm to determine an amplitude of the voltage measurement signal; and

using at least one algorithm to select a PLL regulator state as a function of the amplitude of the voltage measurement signal.

4. A method in accordance with claim **2** wherein using at least one algorithm within the PLL to generate at least one electrical machine control signal comprises:

selecting at least one gain constant numerical value and at least one limit numerical value from a plurality of gain constant numerical values and a plurality of limit numerical values as a function of the PLL regulator state; and

applying the selected gain constant numerical value and the selected limit numerical value to the at least one algorithm.

5. A method in accordance with claim **4** wherein selecting at least one gain constant numerical value and at least one limit numerical value comprises selecting at least one maximum limit numerical value and at least one minimum limit numerical value further comprising selecting a range extending between the maximum and minimum limit numerical values as a function of the PLL regulator state.

6. A method in accordance with claim **5** wherein applying the selected gain constant numerical value and the selected limit numerical value to the at least one algorithm comprises:

selecting a first gain constant numerical value and a first range extending between the maximum and minimum limit numerical values for a first PLL regulator state, the first PLL regulator state is indicative of at least one of the PLL not being locked on to the electric power system frequency signal and at least one electric power system voltage amplitude is outside a pre-determined range of values; and

selecting a second gain constant numerical value and a second range extending between the maximum and minimum limit numerical values for a second PLL regulator state, wherein the second gain constant numerical value is less than the first gain constant numerical value, the second range is less than the first range, and the

second PLL regulator state is indicative of the PLL being locked on to the electric power system frequency signal.

7. A control system for an electrical machine, the electrical machine configured to be electrically coupled to an electric power system, wherein the electric power system is configured to transmit at least one phase of electric power to the electrical machine, said control system facilitates the electrical machine remaining electrically connected to the electric power system during and subsequent to at least one of:

at least one voltage amplitude of the electric power system operating outside of a predetermined range for an undetermined period of time; and

a voltage amplitude of each phase of the electric power system decreasing to approximately zero volts for a predetermined period of time, thereby facilitating zero voltage ride through (ZVRT).

8. A control system in accordance with claim 7 comprising at least one algorithm configured to adjust at least one of the following as a function of at least one voltage amplitude of the electric power system:

at least one gain constant numerical value;

at least one maximum limit numerical value; and

at least one minimum limit numerical value.

9. A control system for an electrical machine, the electrical machine configured to be electrically coupled to an electric power system, wherein the electric power system is configured to transmit at least one phase of electric power to the electrical machine, said control system facilitates the electrical machine remaining electrically connected to the electric power system during and subsequent to at least one voltage amplitude of the electric power system operating outside of a predetermined range for an undetermined period of time, said control system comprising at least one phase-locked loop (PLL) regulator coupled in electronic data communication with at least a portion of the electric power system, said PLL regulator comprising:

at least one PLL comprising at least one phase detection scheme and at least one proportional-integral (PI) filter scheme; and

at least one PLL state machine coupled in electronic data communication with at least a portion of said PLL.

10. A control system in accordance with claim 9 wherein said PI filter scheme comprises:

at least one proportional gain algorithm configured to receive at least one proportional gain constant selected from a plurality of proportional gain constants as a function of at least one voltage amplitude of the electric power system, said proportional gain algorithm further configured to generate a proportional gain signal;

at least one integral gain algorithm configured to receive at least one integral gain constant selected from a plurality of integral gain constants as a function of at least one voltage amplitude of the electric power system, said integral gain algorithm further configured to generate an integral gain signal;

at least one integral filter algorithm configured to receive at least one integral filter limit selected from a plurality of integral filter limits as a function of at least one voltage amplitude of the electric power system, said integral filter algorithm further configured to generate a filtered integral signal;

at least one summation algorithm configured to receive and sum said proportional gain and filtered integral signals and generate a summation signal; and

at least one summation filter algorithm configured to receive at least one summation filter limit selected from a plurality of summation filter limits as a function of at least one voltage amplitude of the electric power system.

11. A control system in accordance with claim 10 wherein said PLL state machine comprises at least one algorithm configured to determine a state of said PLL regulator as a function of at least one voltage amplitude of the electric power system and at least one table of numerical values comprising at least:

said plurality of proportional gain constants;

said plurality of integral gain constants;

said plurality of integral filter limits; and

said plurality of summation filter limits.

12. A control system in accordance with claim 10 wherein said PLL state machine is configured to transmit at least one of the following as a function of said PLL regulator state:

said proportional gain constant selected from said plurality of proportional gain constants;

said integral gain constant selected from said plurality of integral gain constants;

said integral filter limit selected from said plurality of integral filter limits; and

said summation filter limit selected from said plurality of summation filter limits.

13. A wind turbine comprising:

at least one electric power generator configured to be electrically coupled to an electric power system, wherein the electric power system is configured to transmit at least one phase of electric power to and from said generator;

at least one control system configured to be electrically coupled to the electric power system, said control system facilitates the electrical machine remaining electrically connected to the electric power system during and subsequent to at least one voltage amplitude of the electric power system operating outside of a predetermined range for an undetermined period of time; and

at least one phase-locked loop (PLL) regulator coupled in electronic data communication with at least a portion of the electric power system, said PLL regulator comprising:

at least one PLL comprising at least one phase detection scheme and at least one proportional-integral (PI) filter scheme; and

at least one PLL state machine coupled in electronic data communication with at least a portion of said PLL.

14. A wind turbine in accordance with claim 13 comprising at least one algorithm configured to adjust at least one of the following as a function of at least one voltage amplitude of the electric power system:

at least one gain constant numerical value;

at least one maximum limit numerical value; and

at least one minimum limit numerical value.

15. A wind turbine in accordance with claim 13 wherein said PI filter scheme comprises:

at least one proportional gain algorithm configured to receive at least one proportional gain constant selected from a plurality of proportional gain constants as a function of at least one voltage amplitude of the electric power system, said proportional gain algorithm further configured to generate a proportional gain signal;

at least one integral gain algorithm configured to receive at least one integral gain constant selected from a plurality of integral gain constants as a function of at least one voltage amplitude of the electric power system, said integral gain algorithm further configured to generate an integral gain signal;

at least one integral filter algorithm configured to receive at least one integral filter limit selected from a plurality of

integral filter limits as a function of at least one voltage amplitude of the electric power system, said integral filter algorithm further configured to generate a filtered integral signal;

at least one summation algorithm configured to receive and sum said proportional gain and filtered integral signals and generate a summation signal; and

at least one summation filter algorithm configured to receive at least one summation filter limit selected from a plurality of summation filter limits as a function of at least one voltage amplitude of the electric power system.

16. A wind turbine in accordance with claim **15** wherein said PLL state machine comprises at least one algorithm configured to determine a state of said PLL regulator as a function of at least one voltage amplitude of the electric power system and at least one table of numerical values comprising at least:

said plurality of proportional gain constants;

said plurality of integral gain constants;

said plurality of integral filter limits; and

said plurality of summation filter limits.

17. A wind turbine in accordance with claim **15** wherein said PLL state machine is configured to transmit at least one of the following as a function of said PLL regulator state:

said proportional gain constant selected from said plurality of proportional gain constants;

said integral gain constant selected from said plurality of integral gain constants;

said integral filter limit selected from said plurality of integral filter limits; and

said summation filter limit selected from said plurality of summation filter limits.

* * * * *

JS 44 (TXND Rev 1/10)

ORIGINAL

CIVIL COVER SHEET

The JS 44 civil cover sheet and the information contained herein neither replace nor supplement the filing and service of pleadings or other papers as required by law, except as provided by local rules of court. This form, approved by the Judicial Conference of the United States in September 1974, is required for the use of the Clerk of Court for the purpose of initiating the civil docket sheet. (SEE INSTRUCTIONS ON THE REVERSE OF THE FORM)

I. (a) PLAINTIFFS
General Electric Company

DEFENDANTS
Mitsubishi Heavy Industries, Ltd., Mitsubishi Heavy Industries America, Inc., and Mitsubishi Power Systems Americas, Inc.

(b) County of Residence of First Listed Plaintiff
(EXCEPT IN U S PLAINTIFF CASES)

County of Residence of First Listed Defendant
(IN U S PLAINTIFF CASES ONLY)
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BY

(c) Attorney's (Firm Name, Address, and Telephone Number)
Weil, Gotshal & Manges LLP
200 Crescent Court, Suite 300, Dallas TX 75201
Phone: (214) 746-7700

Attorneys (If Known)

3-10CV-276-F

II. BASIS OF JURISDICTION (Place an "X" in One Box Only)

- ☐ 1 U S Government Plaintiff
- ☒ 3 Federal Question (U S Government Not a Party)
- ☐ 2 U S Government Defendant
- ☐ 4 Diversity (Indicate Citizenship of Parties in Item III)

III. CITIZENSHIP OF PRINCIPAL PARTIES (Place an "X" in One Box for Plaintiff and One Box for Defendant) (For Diversity Cases Only)

	PTF	DEF		PTF	DEF
Citizen of This State	☐ 1	☐ 1	Incorporated *or* Principal Place of Business In This State	☐ 4	☐ 4
Citizen of Another State	☒ 2	☒ 2	Incorporated *and* Principal Place of Business In Another State	☒ 5	☒ 5
Citizen or Subject of a Foreign Country	☐ 3	☒ 3	Foreign Nation	☐ 6	☒ 6

IV. NATURE OF SUIT (Place an "X" in One Box Only)

CONTRACT
- ☐ 110 Insurance
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- ☐ 140 Negotiable Instrument
- ☐ 150 Recovery of Overpayment & Enforcement of Judgment
- ☐ 151 Medicare Act
- ☐ 152 Recovery of Defaulted Student Loans (Excl Veterans)
- ☐ 153 Recovery of Overpayment of Veteran's Benefits
- ☐ 160 Stockholders' Suits
- ☐ 190 Other Contract
- ☐ 195 Contract Product Liability
- ☐ 196 Franchise

REAL PROPERTY
- ☐ 210 Land Condemnation
- ☐ 220 Foreclosure
- ☐ 230 Rent Lease & Ejectment
- ☐ 240 Torts to Land
- ☐ 245 Tort Product Liability
- ☐ 290 All Other Real Property

TORTS

PERSONAL INJURY
- ☐ 310 Airplane
- ☐ 315 Airplane Product Liability
- ☐ 320 Assault, Libel & Slander
- ☐ 330 Federal Employers' Liability
- ☐ 340 Marine
- ☐ 345 Marine Product Liability
- ☐ 350 Motor Vehicle
- ☐ 355 Motor Vehicle Product Liability
- ☐ 360 Other Personal Injury

PERSONAL INJURY
- ☐ 362 Personal Injury - Med Malpractice
- ☐ 365 Personal Injury - Product Liability
- ☐ 368 Asbestos Personal Injury Product Liability

PERSONAL PROPERTY
- ☐ 370 Other Fraud
- ☐ 371 Truth in Lending
- ☐ 380 Other Personal Property Damage
- ☐ 385 Property Damage Product Liability

CIVIL RIGHTS
- ☐ 441 Voting
- ☐ 442 Employment
- ☐ 443 Housing/ Accommodations
- ☐ 444 Welfare
- ☐ 445 Amer w/Disabilities - Employment
- ☐ 446 Amer w/Disabilities - Other
- ☐ 440 Other Civil Rights

PRISONER PETITIONS
- ☐ 510 Motions to Vacate Sentence

Habeas Corpus:
- ☐ 530 General
- ☐ 535 Death Penalty
- ☐ 540 Mandamus & Other
- ☐ 550 Civil Rights
- ☐ 555 Prison Condition

FORFEITURE/PENALTY
- ☐ 610 Agriculture
- ☐ 620 Other Food & Drug
- ☐ 625 Drug Related Seizure of Property 21 USC 881
- ☐ 630 Liquor Laws
- ☐ 640 R R & Truck
- ☐ 650 Airline Regs
- ☐ 660 Occupational Safety/Health
- ☐ 690 Other

LABOR
- ☐ 710 Fair Labor Standards Act
- ☐ 720 Labor/Mgmt Relations
- ☐ 730 Labor/Mgmt Reporting & Disclosure Act
- ☐ 740 Railway Labor Act
- ☐ 790 Other Labor Litigation
- ☐ 791 Empl Ret Inc Security Act

IMMIGRATION
- ☐ 462 Naturalization Application
- ☐ 463 Habeas Corpus - Alien Detainee
- ☐ 465 Other Immigration Actions

BANKRUPTCY
- ☐ 422 Appeal 28 USC 158
- ☐ 423 Withdrawal 28 USC 157

PROPERTY RIGHTS
- ☐ 820 Copyrights
- ☒ 830 Patent
- ☐ 840 Trademark

SOCIAL SECURITY
- ☐ 861 HIA (1395ff)
- ☐ 862 Black Lung (923)
- ☐ 863 DIWC/DIWW (405(g))
- ☐ 864 SSID Title XVI
- ☐ 865 RSI (405(g))

FEDERAL TAX SUITS
- ☐ 870 Taxes (U S Plaintiff or Defendant)
- ☐ 871 IRS—Third Party 26 USC 7609

OTHER STATUTES
- ☐ 400 State Reapportionment
- ☐ 410 Antitrust
- ☐ 430 Banks and Banking
- ☐ 450 Commerce
- ☐ 460 Deportation
- ☐ 470 Racketeer Influenced and Corrupt Organizations
- ☐ 480 Consumer Credit
- ☐ 490 Cable/Sat TV
- ☐ 810 Selective Service
- ☐ 850 Securities/Commodities/ Exchange
- ☐ 875 Customer Challenge 12 USC 3410
- ☐ 890 Other Statutory Actions
- ☐ 891 Agricultural Acts
- ☐ 892 Economic Stabilization Act
- ☐ 893 Environmental Matters
- ☐ 894 Energy Allocation Act
- ☐ 895 Freedom of Information Act
- ☐ 900Appeal of Fee Determination Under Equal Access to Justice
- ☐ 950 Constitutionality of State Statutes

V. ORIGIN (Place an "X" in One Box Only)

☒ 1 Original Proceeding ☐ 2 Removed from State Court ☐ 3 Remanded from Appellate Court ☐ 4 Reinstated or Reopened ☐ 5 Transferred from another district (specify) ☐ 6 Multidistrict Litigation ☐ 7 Appeal to District Judge from Magistrate Judgment

VI. CAUSE OF ACTION
Cite the U.S. Civil Statute under which you are filing **(Do not cite jurisdictional statutes unless diversity)**:
35 U.S.C. §§ 284, 285
Brief description of cause:
Patent infringement lawsuit

VII. REQUESTED IN COMPLAINT: ☐ CHECK IF THIS IS A CLASS ACTION UNDER F.R.C.P. 23 **DEMAND $** CHECK YES only if demanded in complaint: **JURY DEMAND:** ☑ Yes ☐ No

VIII. RELATED CASE(S) IF ANY (See instructions): JUDGE DOCKET NUMBER

DATE
02/11/2010

SIGNATURE OF ATTORNEY OF RECORD
Christopher L. Evans

FOR OFFICE USE ONLY

RECEIPT # AMOUNT APPLYING IFP JUDGE MAG JUDGE